ASSESSING AND MANAGING POTENTIAL HEALTH AND SAFETY ISSUES RELATED TO HIGH VOLTAGE DIRECT CURRENT TRANSMISSION LINES

ASSESSING AND MANAGING POTENTIAL HEALTH AND SAFETY ISSUES RELATED TO HIGH VOLTAGE DIRECT CURRENT TRANSMISSION LINES

Prepared for:

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Hawaii Department of Planning and Economic Development

by :

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OVERVIEW

- HVDC transmission lines
- HVDC electrical environment
- Biological effects of air ions and electric fields
- Assessment and management of actual vs. perceived risk
- Case illustration

ADVANCES IN HIGH VOLTAGE DC TRANSMISSION

- Stabilizing effects on interconnected power systems
- Lower line losses over long distances
- No equipment needed for line inductance and capacitance compensation
- Two conductors instead of three (AC)
- Switching between DC and AC for transmission and distribution

HVDC LOCATIONS

United States, Canada, Brazil, Denmark, Sweden, Norway, Italy, Japan, New Zealand, USSR, Zaire, Mozambique, South Africa

- Pacific Northwest - Pacific Southwest Intertie 1970
  - 846 miles
  - ±500 kV
  - 2000 MW (by 1988, 3200 MW)
- The Nelson River Bipole I 1977
  - 553 miles
  - ±450 kV
  - 1620 MW
- Square Butte Line 1977
  - 465 miles
  - ±250 kV
  - 500 MW
- The Nelson River Bipole II 1978
  - 578 miles
  - ±250 kV (By 1986, ±500 kV)
  - 1000 MW (By 1986, 1800 MW)
- Coal Creek Project (CU Line) 1979
  - 436 miles
  - ±400 kV
  - 1000 MW
- Intermountain Power Project 1986
  - 500 miles
  - ±500 kV
  - 1500 MW
- New England - Hydro-Quebec Phase I 1986
  - 107 miles
  - ±450 kV
  - 690 MW

LINES PLANNED ON OR UNDER CONSTRUCTION IN NORTH AMERICA

- New England - Quebec Phase II 1990
  - 600 + 133 miles
  - ±450 kV
  - 2000 MW
- Walker County STP Tie
  - 155 miles
  - ±400 kV
  - 1040 MW
- Mead-Phoenix Project
  - 240 miles
  - ±364 kV (to be uprated to ±500 kV)
  - 1600 MW (to be uprated to 2200 MW)
- Nelson River Bi pole II
- Mead - Los Angeles Project
- Hawaiian Electric Company

CORONA EFFECT:

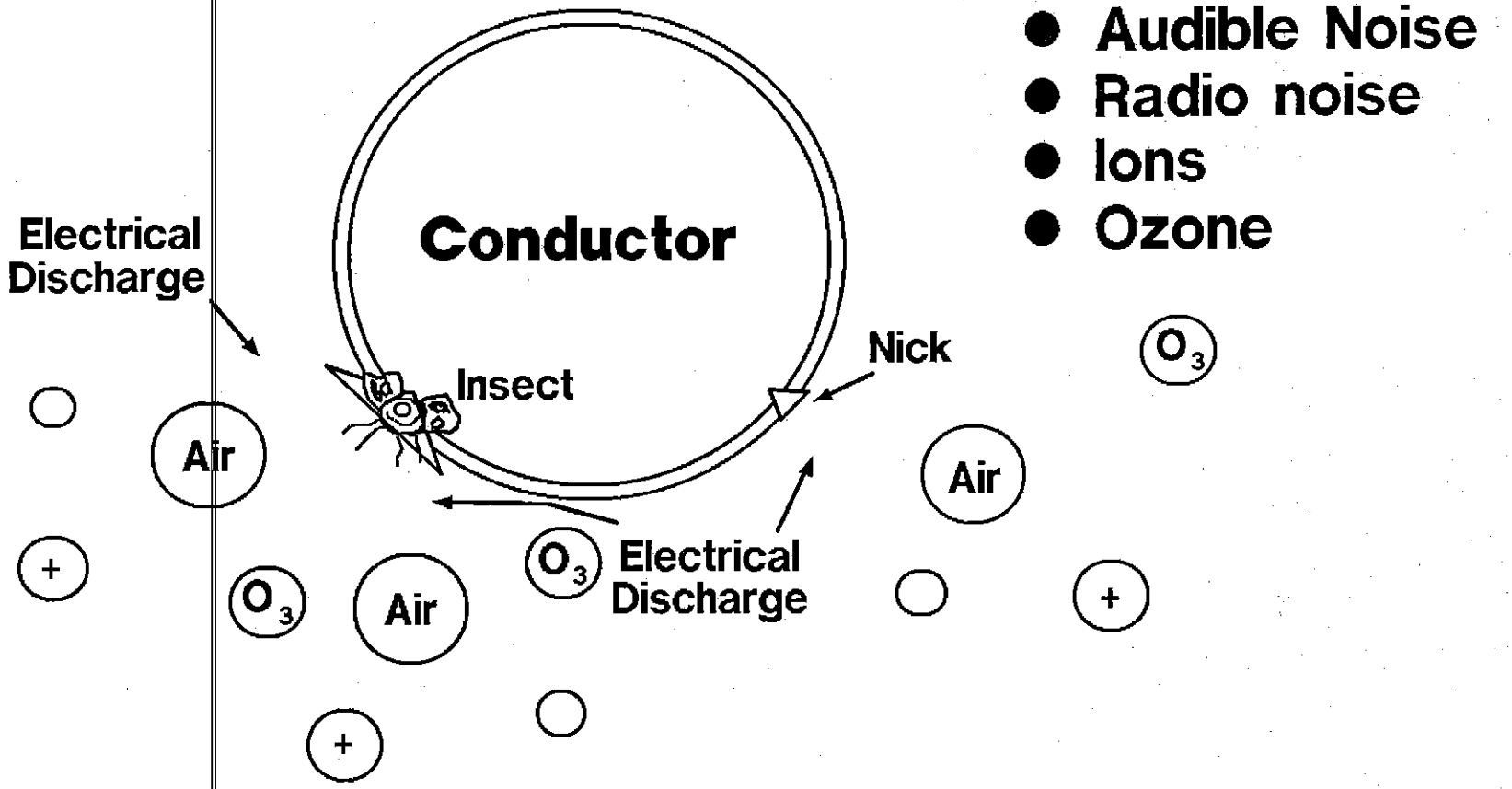
The partial electrical breakdown of air into charged particles

- **Occurs when conductor surface voltage gradient exceeds insulation strength of air**

CORONA

(Electrical Discharge in Air)

- Audible Noise
- Radio noise
- Ions
- Ozone



Factors Affecting Air Ion Concentrations

- Corona inception gradient
- Conductor diameter and bundle
- Pole spacing
- Line height
- Local meterological conditions, e.g. wind, RH

ION CURRENT

- Conduction current resulting from charge migration

- Convection current –
  the transport of charge by air motion

AIR ION GENERATION AND TRANSPORT TO GROUND

- Size
- Mobility: 1 - 2 $cm^2/v\text{-}s$ (1 - 2 cm/sec/v/cm)
- Speed of ions from conductor to ground
- Modes of transport
  - Electrical forces - Dependent on proximity to line
  - Convective forces - Dependent on wind speed
- Ions attaching to aerosols
- Natural levels
  - Atmospheric conditions
  - Geographic locations
  - Air quality

ION CONCENTRATION COMPARED TO COMMON POLLUTANTS

- CO is harmful at 50 ppm
- NO_2 induces respiratory damage at 0.8 ppm
- NO_2 is safe below 0.14 ppm
- O_3 is safe below 0.12 ppm
- 10^5 ions/cc -- .0000000037 ppm
- It is therefore extremely unlikely that this is a threat to health

OTHER CORONA EFFECTS

- **Audible noise**
- **Electromagnetic interference (RI, TVI)**
- **Generation of oxidants**
- **Visible light**

DC ELECTRIC FIELD

Nominal field

- A function of voltage on the conductors
- A function of the line geometry
  - Line height
  - Pole spacing
- Significant component of the total field
- Two sets of conductor bundles, one positive, one negative
- Field strength dependent on distance from the line

DC ELECTRIC FIELD

Space charge field

- A function of corona generated charge
- A function of line voltage and corona intensity
- A function of the line geometry and conductor dimensions
  - Line height
  - Pole spacing
  - Conductor diameter
  - Number of conductor
- Variable, dependent on the environment
- Field strength dependent on distance from the line
  - Under the line
  - At the edge of the right of way

DC MAGNETIC FIELD

- A function of current on line
- Decreases with distance from the conductor
- Less than or similar to the Earth's magnetic field (0.6 Gauss)
- No laboratory evidence of harmful effect up to 10^3 Gauss

Biological Effects of Air Ions

Status of Research

- Provocative findings
- Wide range of effects studied
- Effects/no effects
- Short-term/long-term
- No dose-response or time-course
- Uneven quality

BIOLOGICAL AND BEHAVIORAL EFFECTS

Difficulties in interpretation

- **Lack of controls**
- **Poor experimental design**
- **Wide variety of experimental conditions**
- **Incorrect statistical procedures**

RISK ASSESSMENT

- Hazard identification
- Dose-response
- Exposure assessment
- Risk characterization

EFFECT VS. HARM

- Characterize agent
  - -stimulus
  - -stressor
  - -toxicant
- Characterize response
  - -magnitude
  - -duration

RESPONSE CHARACTERIZATION MODEL: GENERAL ADAPTATION SYNDROME

- Alarm reaction
  - Incompatibility or adaptation
- Resistance
  - Recuperation
  - Replenishing
- Exhaustion
  - Local stress, local adaptation energy
    - Complete consumption of local adaptation energy resources
  - Accelerated aging process
    - Decline and death

ASSESSMENT AND MANAGEMENT

OF

RISK PERCEPTION

ERI STRATEGIC APPROACH FOR ASSESSING RISK AND MANAGING RISK PERCEPTION

- Format database for use by management, legal staff and regulators
- Analyze and interpret database for specific application in transmission line permitting process
- Develop method for communicating elements of complex database to management, legal staff and regulators
- Media analysis
- Identification of critical health effects issues
- Issue management
- Evaluation of implications of scientific literature for transmission lines

Use of Air Ion Database in Context of Transmission Line Issues

Quality Analysis

Comparative Analysis

- Identification of endpoints in ion studies
- Identification of other environmental stimuli
- Comparative results

COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN RESPIRATORY RESPONSES

Author & Year	Environmental Stimulus	Reported Change
Robinson & Jones, 1982	Feedback on breathing	264.9%
Kisselkova & Georgiev, 1979	Exercise	100.0
Penaloza-Rojas & Fajardo-Bolanos, 1981	Feedback on breathing over 10 minutes	43.8
Hartung et al., 1980	Exercise	42.5
Burgess & Whitelaw, 1984	Breathing cold air	39.5
Palti et al., 1965	10^4 (-) ions/cm^3	28.7
Reilly & Brooks, 1982	None (daily variation over time, 6 PM to 6 AM)	16.3
Josenhans et al., 1969	Cold water applied to face skin surface	14.0
Palti et al., 1965	10^4 (+) ions/cm^3	10.0
Ben-dov et al., 1963	10^5 (-) ions/cm^3	7.0
Osterballe et al., 1979	10^4 (+) ions/cm^3 10^4 (-) ions/cm^3	6.9 3.9
Albrechtsen et al., 1978	10^3 (+) ions/cm^3 10^3 (-) ions/cm^3	0 0
Wagner et al., 1983	10^4 (+) ions/cm^3	0
Motley & Yanda, 1966	10^5 (+) ions/cm^3 10^5 (-) ions/cm^3	0 0
Dantzler et al., 1983	10^5 (+) ions/cm^3 10^5 (-) ions/cm^3	0 0
McDonald et al., 1967	10^6 (+) ions/cm^3 10^6 (-) ions/cm^3	0 0
Yaglou et al., 1933	10^6 (+) ions/cm^3 10^6 (-) ions/cm^3	0 0

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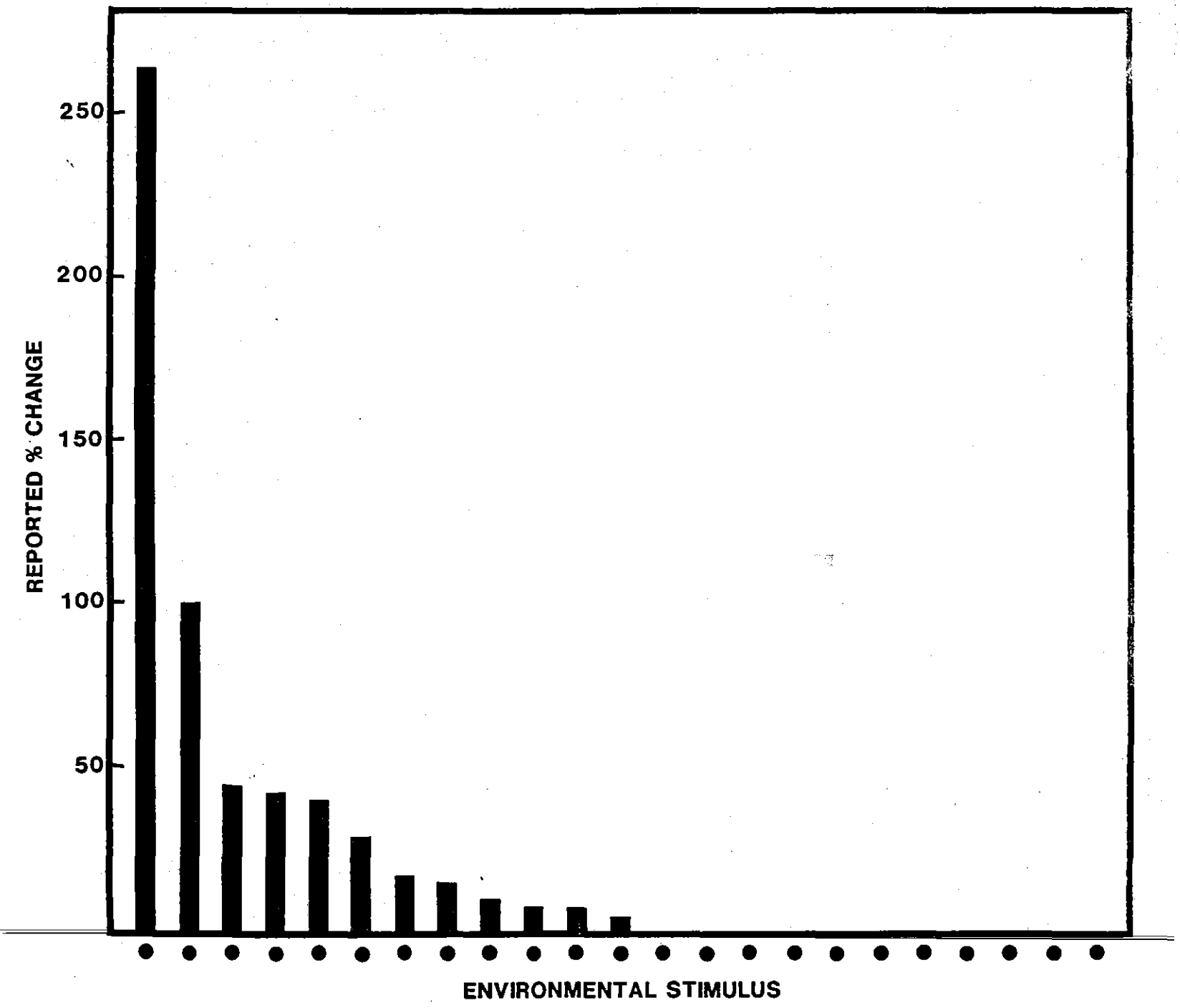
ENVIRONMENTAL STIMULI: HUMAN RESPIRATORY RESPONSES

- Feedback on breathing
- Exercise
- Feedback on breathing over 10 minutes
- Exercise
- Breathing cold air
- None (daily variation over time, 6 PM to 6AM)
- Cold water applied to face skin surface
- $\pm 10^4$ to $\pm 10^6$ ions/cm^3

COMPARISON:

HUMAN RESPIRATORY RESPONSES



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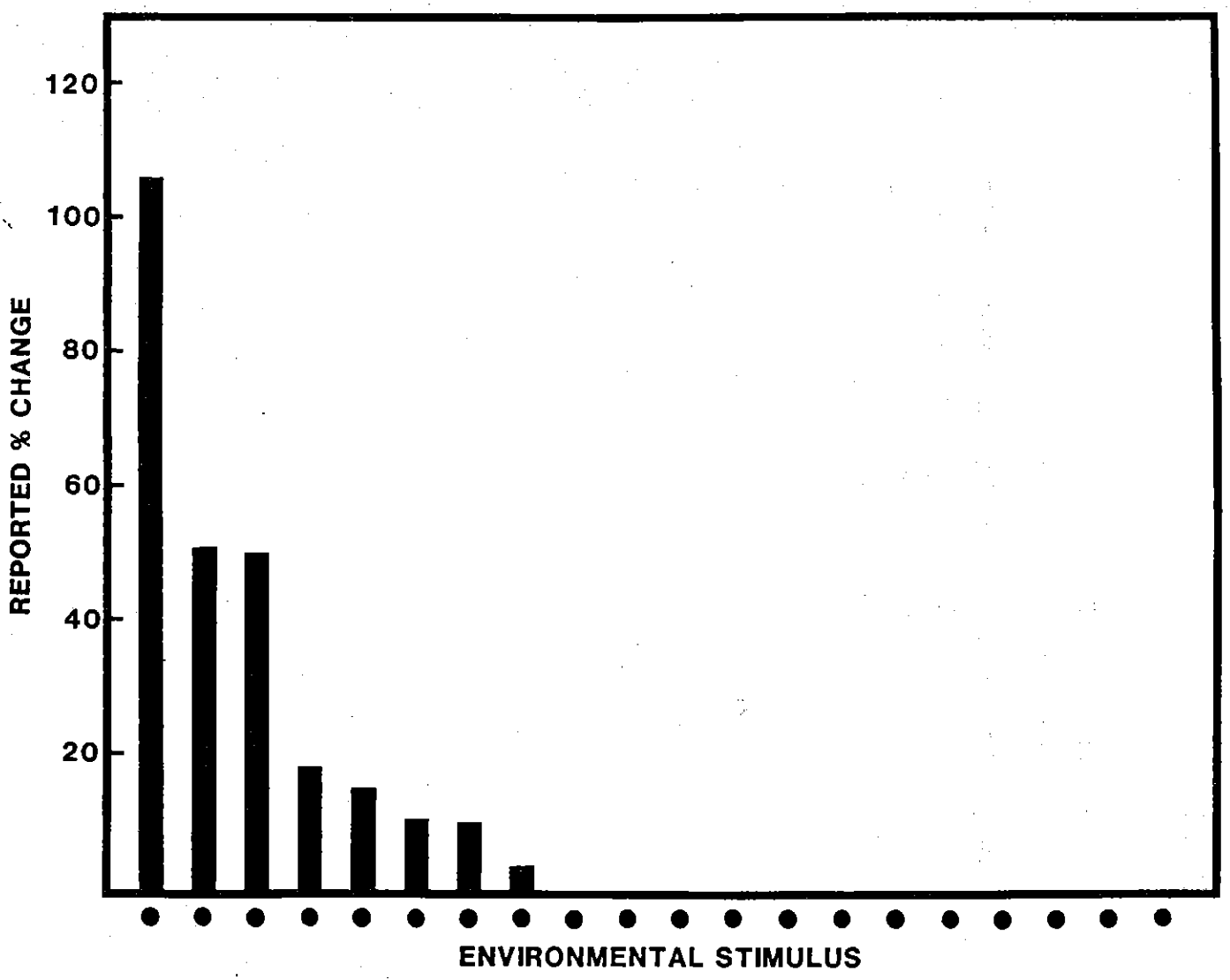
COMPARISON CHART
AIR IONS AND BIOLOGICAL VARIABILITY
HUMAN PULSE AND HEART RATE

Author & Year	Environmental Stimulus	Reported Change
Smutok et al., 1980	Exercise	106.8%
Borg, 1982	Exercise	50.7
Metcalf et al., 1981	Aerobic activity	49.9
Pequignot et al., 1985	Bed rest	18.2
Frankenhauser et al., 1971	Differences in visual stimulation	15.6
Inbar et al., 1982	10^5 (-) ions/cm^3	9.3
Faria & Drummond, 1982	None (daily variation over time, 6 PM to 6 AM)	9.0
Sovijarvi et al., 1979	10^4 (+/-) ions/cm^3	3.8
Barron & Dreher, 1964	10^3 (-) ions/cm^3	0
Albrechtsen et al., 1978	10^3 (+) ions/cm^3 10^3 (-) ions/cm^3	0 0
Monaco & Acker, 1963	10^4 (+) ions/cm^3 10^4 (-) ions/cm^3	0 0
Sulman et al., 1978	10^4 (-) ions/cm^3	0
Dantzler et al., 1983	10^5 (+) ions/cm^3 10^5 (-) ions/cm^3	0 0
McDonald et al., 1967	10^6 (+) ions/cm^3 10^6 (-) ions/cm^3	0 0
Yaglou et al., 1933	10^6 (+) ions/cm^3 10^6 (-) ions/cm^3	0 0

ENVIRONMENTAL STIMULI: HUMAN PULSE AND HEART RATE

- Exercise
- Aerobic activity
- Bed rest
- Differences in visual stimulation
- None (daily variation over time, 6PM to 6AM)
- $\pm 10^3$ to $\pm 10^6$ ions/cm^3

COMPARISON:
HUMAN PULSE AND HEART RATE



COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN NEUROCHEMICAL RESPONSES

Author & Year	Environmental Stimulus	Reported Change
Barbau & Wilkoff, 1959	Eating bananas	933.3%
Bajatti & Riederer, 1976	Meditation	326.3
Fibiger et al., 1984b	None (daily variation over time, 8 AM to 8 PM)	160.0
Mori, 1982	None (daily variation over time, 4 PM to Midnight)	142.9
Fibiger et al., 1984b	Physical effort (low)	90.0
Fibiger et al., 1984a	Mental effort	76.2
Sulman et al., 1978	10^4 (-) ions/cm^3	51.0
Sulman et al., 1978	10^4 (-) ions/cm^3	38.0
Sulman et al., 1978	10^4 (-) ions/cm^3	5.7
Barron & Dreher, 1964	10^3 (-) ions/cm^3	0

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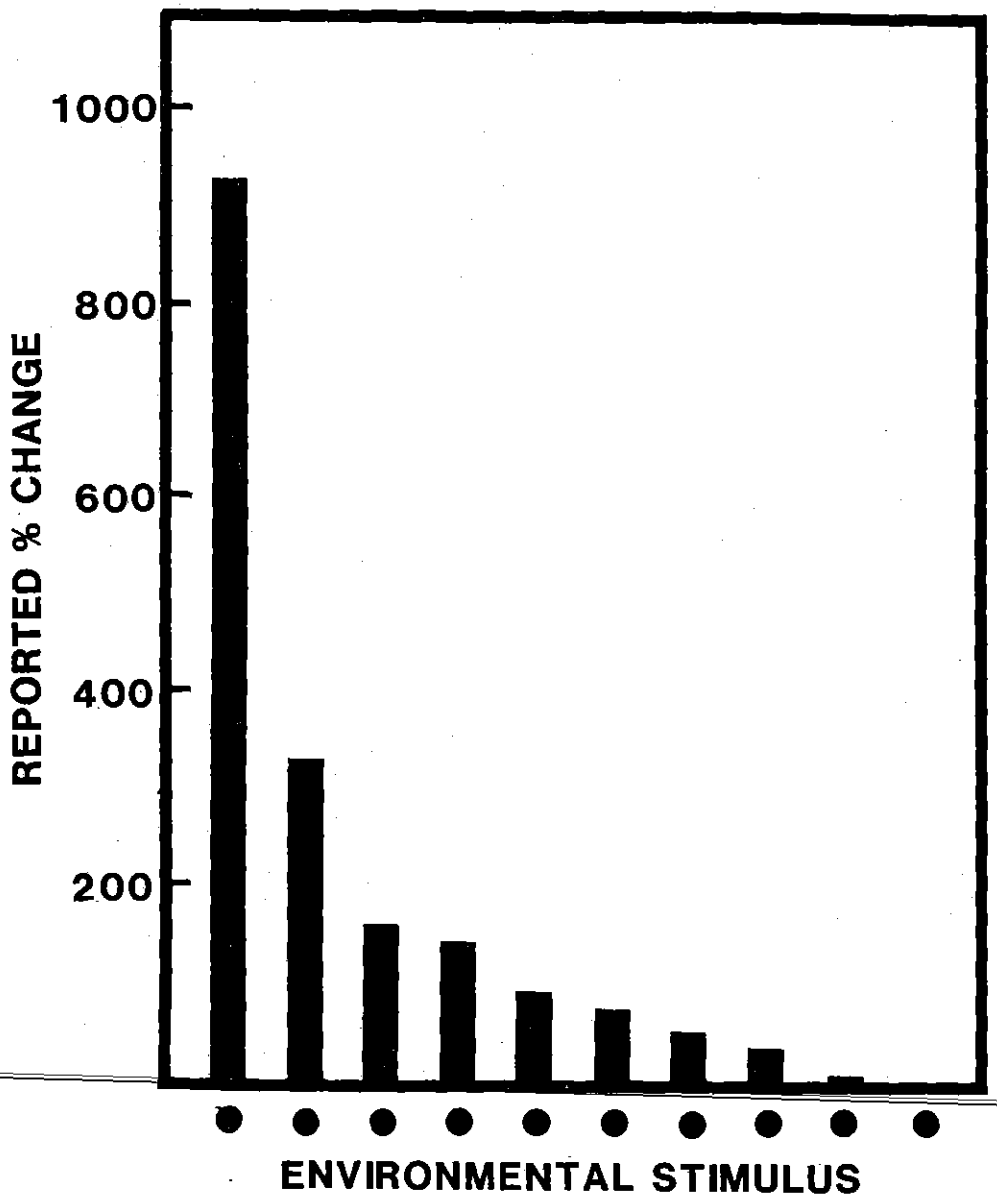
ENVIRONMENTAL STIMULI: HUMAN NEUROCHEMICAL RESPONSES

- Eating bananas
- Meditation
- None (daily variation over time, 8 AM to 8 PM)
- None (daily variation over time, 4 PM to Midnight)
- Physical effort (low)
- Mental effort
- -10^3 to -10^4 ions/cm^3

COMPARISON:

HUMAN NEUROCHEMICAL RESPONSES



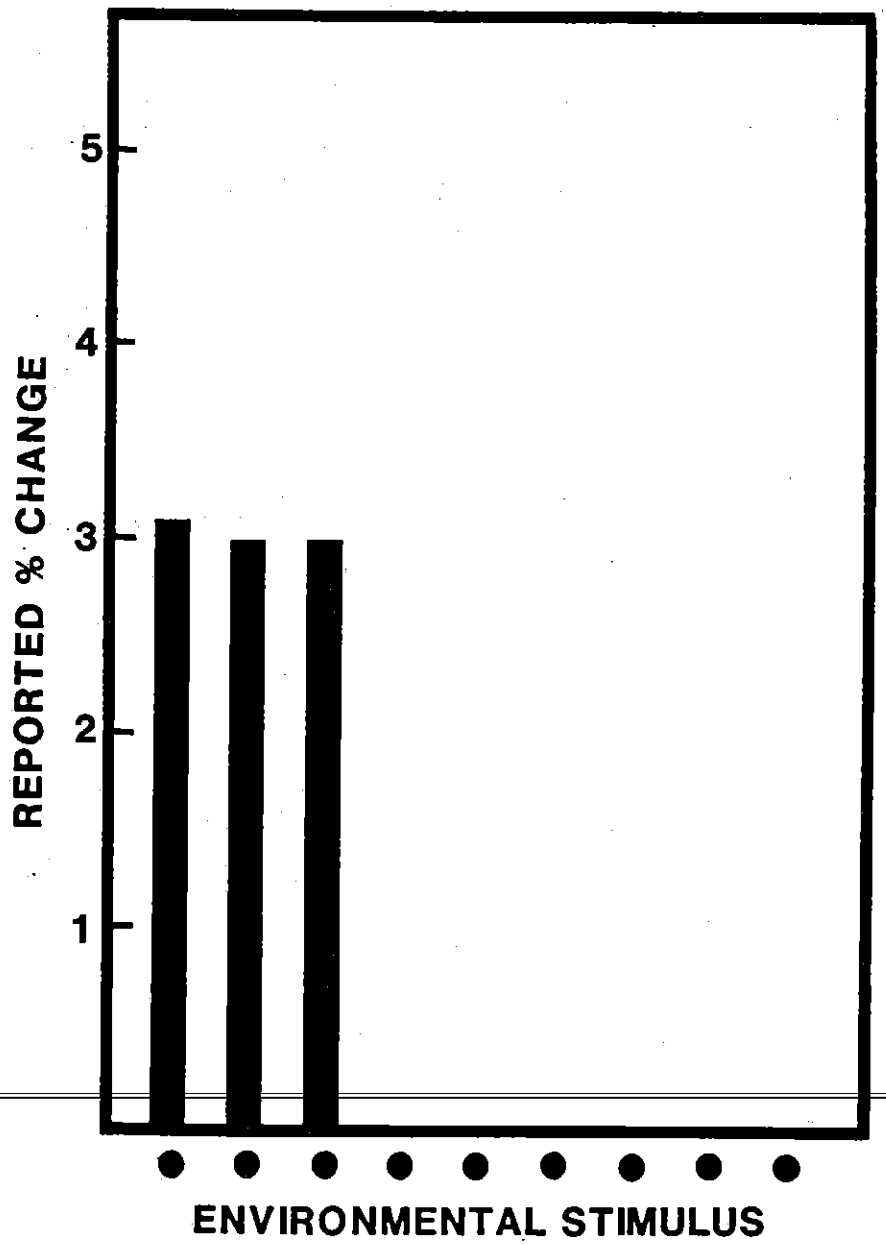
COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN BODY
(SKIN SURFACE AND INTERNAL) TEMPERATURE

Author & Year	Environmental Stimulus	Reported Change
Mori, 1982	None (daily variation over time, 8 AM to 12 Midnight)	3.1%
Faria & Drummond,	None (daily variation over time 6 AM to 6 PM)	3.0
Inbar et al., 1982	10^5 (-) ions/cm^3	3.0
Albrechtsen et al., 1978	10^3 (+) ions/cm^3 10^3 (-) ions/cm^3	0 0
Sulman et al., 1978	10^4 (-) ions/cm^3	0
Inbar et al., 1982	10^5 (-) ions/cm^3	0
Yaglou et al., 1933	10^6 (+) ions/cm^3 10^6 (-) ions/cm^3	0 0

ENVIRONMENTAL STIMULI:
HUMAN BODY TEMPERATURE
(SKIN SURFACE AND INTERNAL)

- None (daily variation over time, 8 AM to 12 Midnight)
- None (daily variation over time, 6 AM to 6 PM)
- $\pm 10^3$ to $\pm 10^6$ ions/cm^3

COMPARISON:
HUMAN BODY TEMPERATURE
(SKIN SURFACE AND INTERNAL)



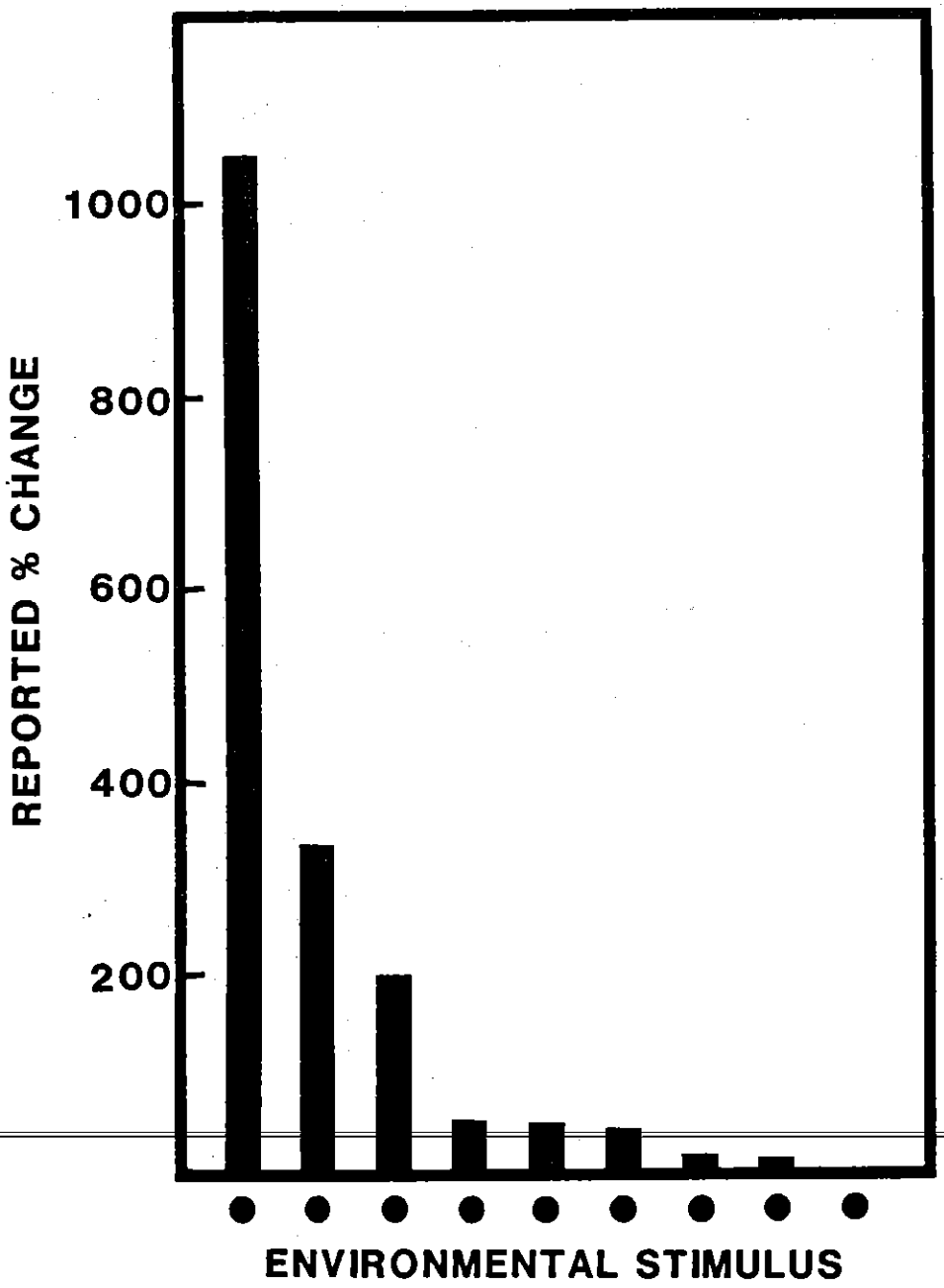
COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN SKIN CONDUCTANCE

Author & Year	Environmental Stimulus	Reported Change
Falk & Kline, 1978	"White" noise	1050.4%
Fenz, 1964	Presentation of arousing words	348.0
Hentschel & Ternes, 1984	Task learning and ordinary differences among people	200.0
Davies & Krkovic, 1965	Doing a task over time (1.5 hours)	48.8
Schulz & Schonpflug, 1981	Listening to moderate noise (dB equivalent of air conditioner)	46.7
Charry & Hawkinshire, 1981	10^4 (+) ions/cm^3	41.5
Wilkinson et al., 1972	Incentive to do a task	15.2
Thackray et al., 1973	None (ordinary differences among people)	13.3
Monaco & Acker,	10^4 (+) ions/cm^3	0

ENVIRONMENTAL STIMULI: HUMAN SKIN CONDUCTANCE

- "White" noise
- Presentation of arousing words
- Task learning and ordinary differences among people
- Doing a task over time (1.5 hours)
- Listening to moderate noise
  (dB equivalent of air conditioner)
- Incentive to do a task
- None (ordinary differences among people)
- $+10^4$ ions/cm^3

COMPARISON:
HUMAN SKIN CONDUCTANCE



COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN BRAIN WAVE RESPONSES

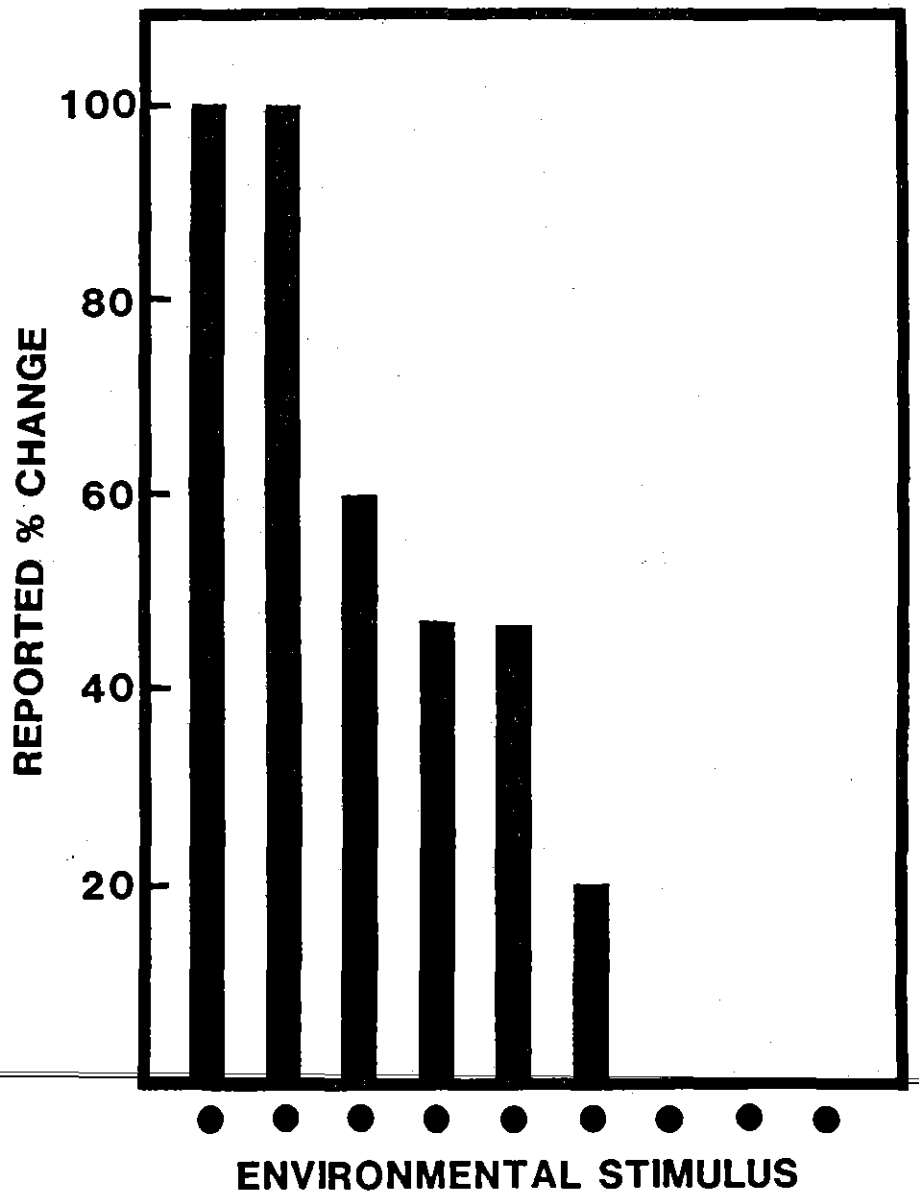
Author & Year	Environmental Stimulus	Reported Change
Mulholland et al., 1983	Visual feedback of information	100.00%
Banquet, 1973	Meditation	100.00
Penaloza-Rojas & Fajardo-Bolanos, 1981	Feedback with eyes open vs. closed	60.0
Marquis et al., 1980	None (eyes open vs. closed)	47.8
Knox, 1980	Quiet concentration	47.0
Assael et al.,	10^5 (-) ions/cm^3	20.1
Silverman & Kornblueh, 1957	10^2 (+) ions/cm^3 10^2 (-) ions/cm^3	0 0
Hedge & Eleftherakis, 1982	10^4 (-) ions/cm^3	0

6-3-41

ENVIRONMENTAL STIMULI: HUMAN BRAIN WAVE RESPONSES

- Visual feedback of information
- Meditation
- Feedback with eyes open vs. closed
- None (eyes open vs. closed)
- Quiet concentration
- $\pm 10^2$ to $\pm 10^4$ ions/cm^3
- -10^5 ions/cm^3

COMPARISON:
HUMAN BRAIN WAVE RESPONSES



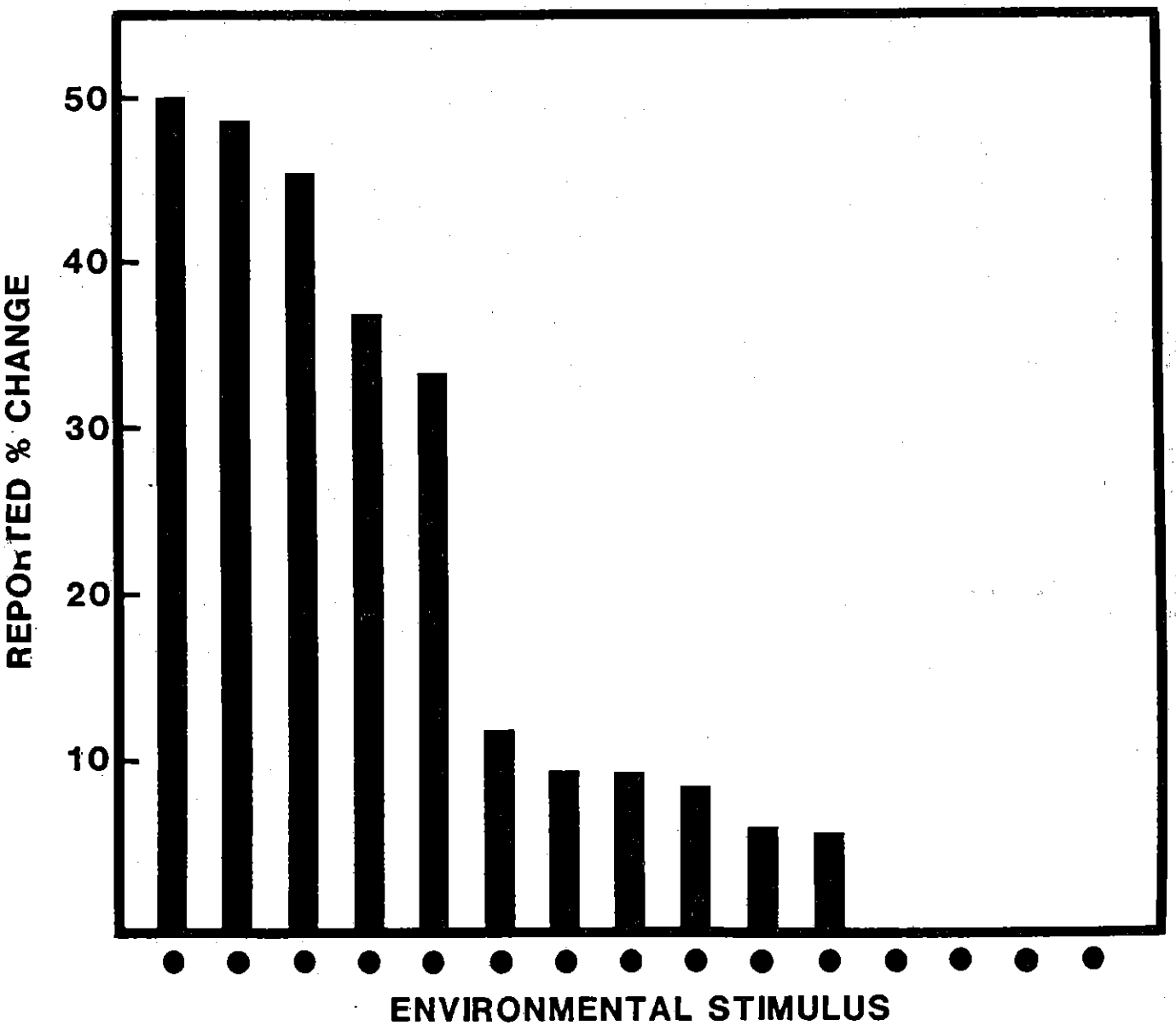
COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN REACTION TIME

Author & Year	Environmental Stimulus	Reported Change
Fenz, 1964	Presentation of arousing words	50.0
Welford, 1958	None (differences in age)	48.7
Wilkinson et al., 1972	Incentive and type of task	45.5
Blake, 1967	None (doing a task at two different times of day, 9 PM vs 8 AM)	37.1
Hartley, 1973	Doing a task twice	33.5
Tom et al., 1981	10^4 (-) ions/cm^3	12.1
Slote, 1961	10^4 (+) ions/cm^3	9.6
Thackray et al., 1974	None (time passing 40 minutes)	9.3
Slote, 1961	10^4 (+) ions/cm^3	8.4
Hawkins & Barker, 1978	10^3 (-) ions/cm^3	6.1
Charry & Hawkinshire, 1981	10^4 (+) ions/cm^3	5.7
Barron & Dreher, 1964	10^3 (-) ions/cm^3	0
Farmer & Bendix, 1982	105 (-) ions/cm^3	0
McDonald et al., 1967	10^6 (-) ions/cm^3 10^6 (+) ions/cm^3	0 0

ENVIRONMENTAL STIMULI: HUMAN REACTION TIME

- Presentation of arousing words
- None (differences in age)
- Incentive and type of task
- None (doing a task at two different times of day, 9 PM vs 8 AM)
- Doing a task twice
- None (time passing 40 minutes)
- $\pm 10^3$ to $\pm 10^6$ ions/cm^3

COMPARISON:
HUMAN REACTION TIME



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COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN VIGILANCE
(i.e. PAYING ATTENTION)

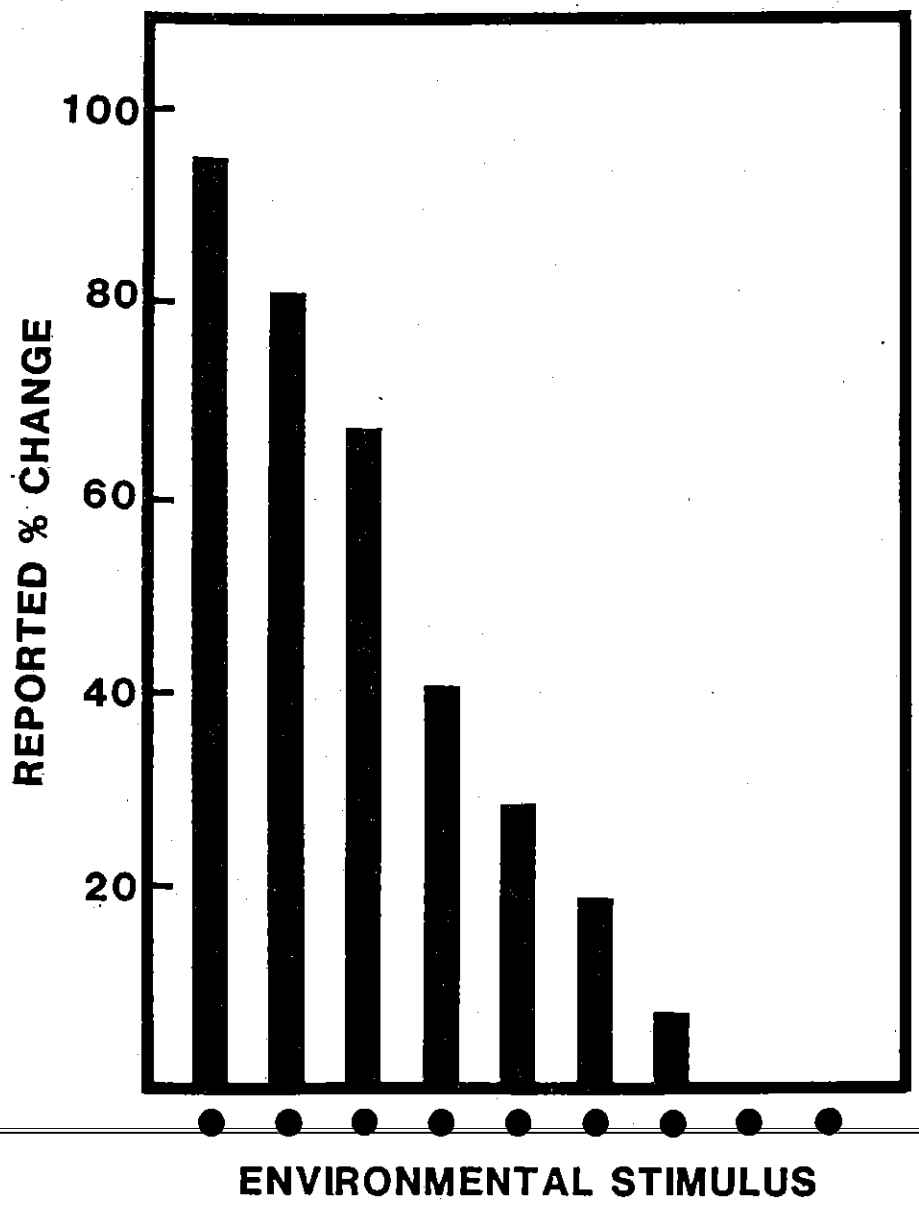
Author & Year	Environmental Stimulus	Reported Change
Loke & Meliska, 1984	None (time passing - 1 hour)	95.6%
Davies & Krkovic, 1965	Doing a task over time (1.5 hours)	81.0
Davies & Hockey, 1966	Getting extra signals during a task	67.6
McDonald et al., 1967	10^6 (+) ions/cm^3	40.7
Frankenhauser et al., 1971	Differences in stimulation and time passing (1 hour)	28.4
McDonald et al., 1967	10^6 (-) ions/cm^3	19.0
Halcomb & Kirk, 1965	10^4 (+/-) ions/cm^3	7.7
Chiles et al., 1960	10^4 (+) ions/cm^3 10^4 (-) ions/cm^3	0 0

ENVIRONMENTAL STIMULI:
HUMAN VIGILANCE (i.e. PAYING ATTENTION)

- None (time passing - 1 hour)
- Doing a task over time (1.5 hours)
- Getting extra signals during a task
- Differences in stimulation
  and time passing (1 hour)
- $\pm 10^4$ to $\pm 10^6$ ions/cm

COMPARISON:

HUMAN VIGILANCE
(i.e. paying attention)



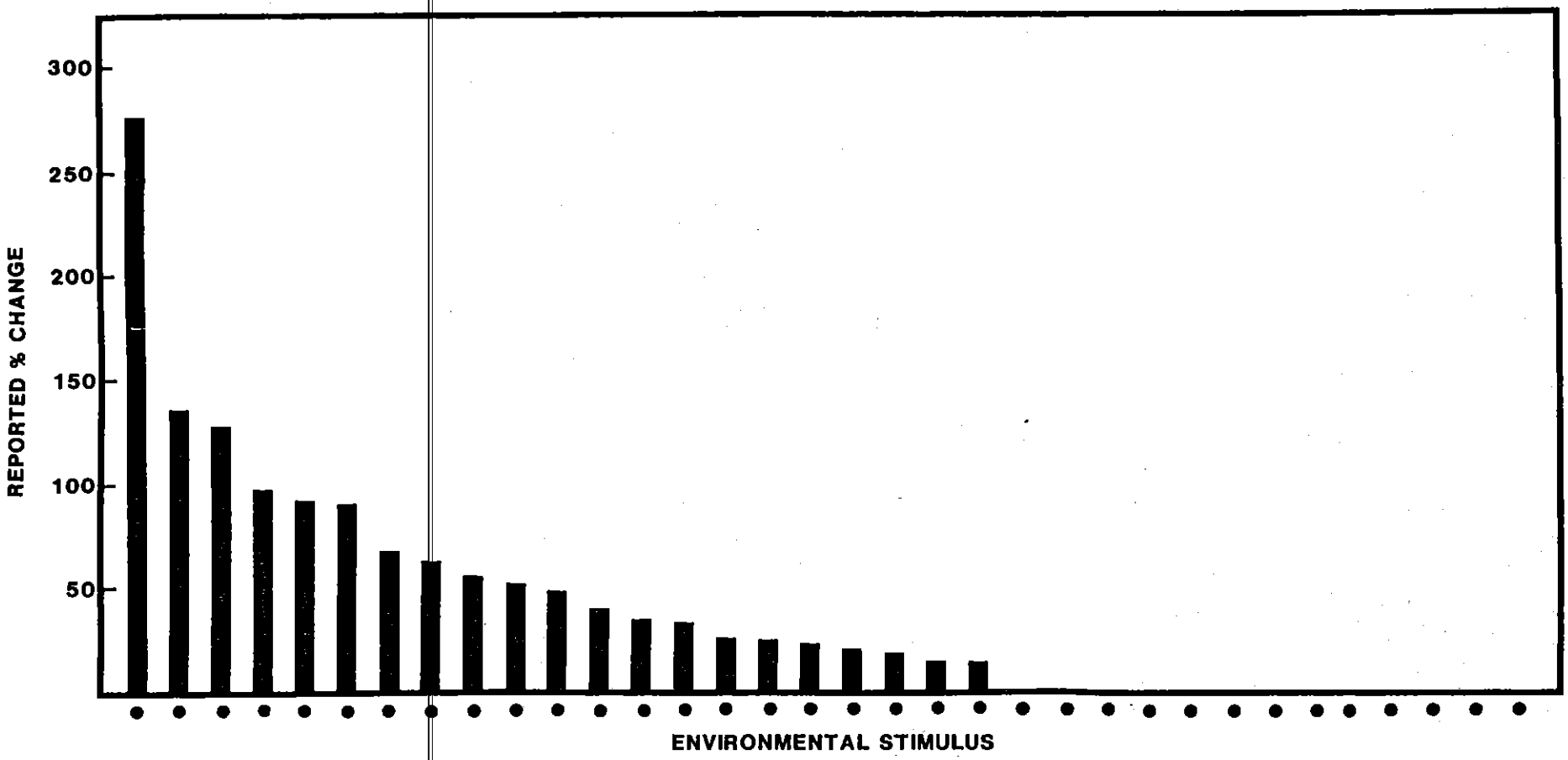
COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN MOOD AND SUBJECTIVE RESPONSES

Author & Year	Environmental Stimulus	Reported Change
Sigel, 1979	None (time passing, 2.25 hours)	275.2%
Nevins et al., 1966	8°F change in temperature (66° - 74°)	136.4
Nevins et al., 1966	4°F change in temperature (66° - 70°)	127.3
Hawkins, 1981	16°F change in temperature (66° - 82°)	97.8
Hawkins, 1981	16°F change in temperature (66° - 82°)	92.2
Hawkins, 1981	10^3 (-) ions/cm^3	91.4
Hawkins, 1981	15% change in relative humidity (65% - 80%)	67.6
McIntyre & Griffiths, 1975	55% change in relative humidity (20% - 75%) at 82°F	62.5
Albrechtsen et al., 1978	10^3 (+) ions/cm^3	56.6
Charry & Hawkinshire, 1981	10^4 (+) ions/cm^3	52.9
Sigel, 1979	10^5 (+) ions/cm^3	49.2
Olmedo et al., 1973	Illumination (lighting) & noise (dB equivalent to a refrigerator)	40.4
Nevins et al., 1966	20% change in relative humidity (35% -55%) at 72°F	35.0
Charry & Hawkinshire, 1981	Experiencing a new situation	33.3
Hawkins, 1981	9°F change in temperature (73° - 82°)	25.5
Nevins et al., 1966	10% change in relative humidity (35% - 45%) at 72°F	25.0
Sigel, 1979	10^5 (-) ions/cm^3	22.5
Olmedo et al., 1973	Illumination (lighting)	20.2
Tom et al., 1981	10^4 (-) ions/cm^3	17.1
Olmedo et al., 1973	Moderate noise (dB equivalent to a refrigerator)	13.9
Hawkins, 1981	10^3 (-) ions/cm^3	13.4
Hawkins & Morris, 1984	10^3 (-) ions/cm^3	0
McGurk, 1959	10^3 (+) ions/cm^3 10^3 (-) ions/cm^3	0 0
Albrechtsen et al., 1978	10^3 (+) ions/cm^3 10^3 (-) ions/cm^3	0 0
Monaco & Acker, 1963	10^4 (+) ions/cm^3 10^4 (-) ions/cm^3	0 0
Chiles et al., 1960	10^4 (+) ions/cm^3 10^4 (-) ions/cm^3	0 0
Ruocco, 1962	10^4 (+) ions/cm^3 10^4 (-) ions/cm^3	0 0
Danzler et al., 1983	10^5 (+) ions/cm^3 10^5 (-) ions/cm^3	0 0

ENVIRONMENTAL STIMULI:
HUMAN MOOD AND SUBJECTIVE RESPONSES

- None (time passing, 2.25 hours)
- 8° F change in temperature (66°-74°)
- 4° F change in temperature (66°-70°)
- 16° F change in temperature (66°-82°)
- 15% change in relative humidity (65% - 80%)
- 55% change in relative humidity (20% - 75%) at 82°F
- Illumination (lighting) & noise (dB equivalent to a refrigerator)
- 20% change in relative humidity (35% - 55%) at 72° F
- Experiencing a new situation
- 9°F change in temperature (73°- 82°)
- 10% change in relative humidity (35% - 45%) at 72° F
- Illumination (lighting)
- Moderate noise (dB equivalent to a refrigerator)
- $\pm 10^3$ to $\pm 10^5$ ions/cm^3

COMPARISON:
HUMAN MOOD AND SUBJECTIVE RESPONSES



COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN PSYCHOMOTOR PERFORMANCE

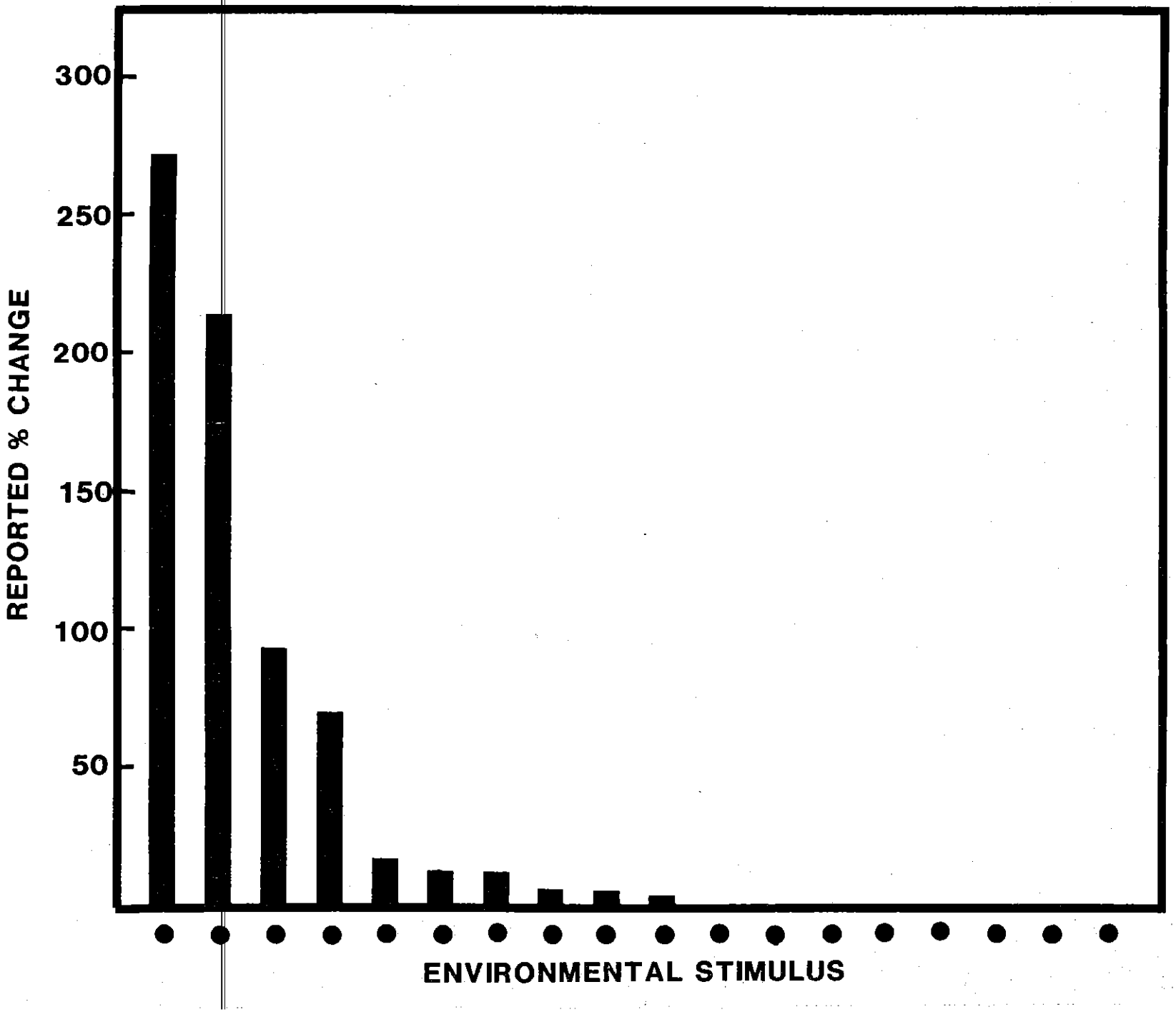
Author & Year	Environmental Stimulus	Reported Change
Powell, 1982	Physical effort (high)	272.4%
Skrandies, 1985	Illumination differences	213.2
Falk & Kline, 1978	None (differences in male vs. female and in age -- 19.1 vs. 70.1 years)	93.7
Harper, 1979	Noise (dB equivalent to refrigerator)	70.0
Morton & Kershner, 1984	10^4 (-) ions/cm^3	17.2
Davidson et al., 1981	Concentration on heart beat and use of left vs. right hand	12.8
Slote, 1961	10^4 (+) ions/cm^3	12.9
Slote, 1961	10^4 (+) ions/cm^3	6.4
Slote, 1961	10^4 (-) ions/cm^3	5.7
Slote, 1961	10^4 (-) ions/cm^3	4.2
Barron & Dreher, 1964	10^3 (-) ions/cm^3	0
Albrechtsen et al., 1978	10^3 (+) ions/cm^3 10^3 (-) ions/cm^3	0 0
McGurk, 1959	10^3 (+) ions/cm^3	0
Slote, 1961	10^4 (+) ions/cm^3	0
Slote, 1961	10^4 (-) ions/cm^3	0
Chiles, et al., 1960	10^4 (+) ions/cm^3 10^4 (-) ions/cm^3	0 0

ENVIRONMENTAL STIMULI:
HUMAN PSYCHOMOTOR PERFORMANCE

- Physical effort (high)
- Illumination differences
- None (differences in male vs. female
  and in age -- 19.1 vs. 70.1 years)
- Noise (dB equivalent to refrigerator)
- Concentration on heart beat and use of left vs. right hand
- $\pm 10^3$ to $\pm 10^4$ ions/cm^3

COMPARISON:

HUMAN PSYCHOMOTOR PERFORMANCE



6-4-5

COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
HUMAN PERCEIVED EXERTION

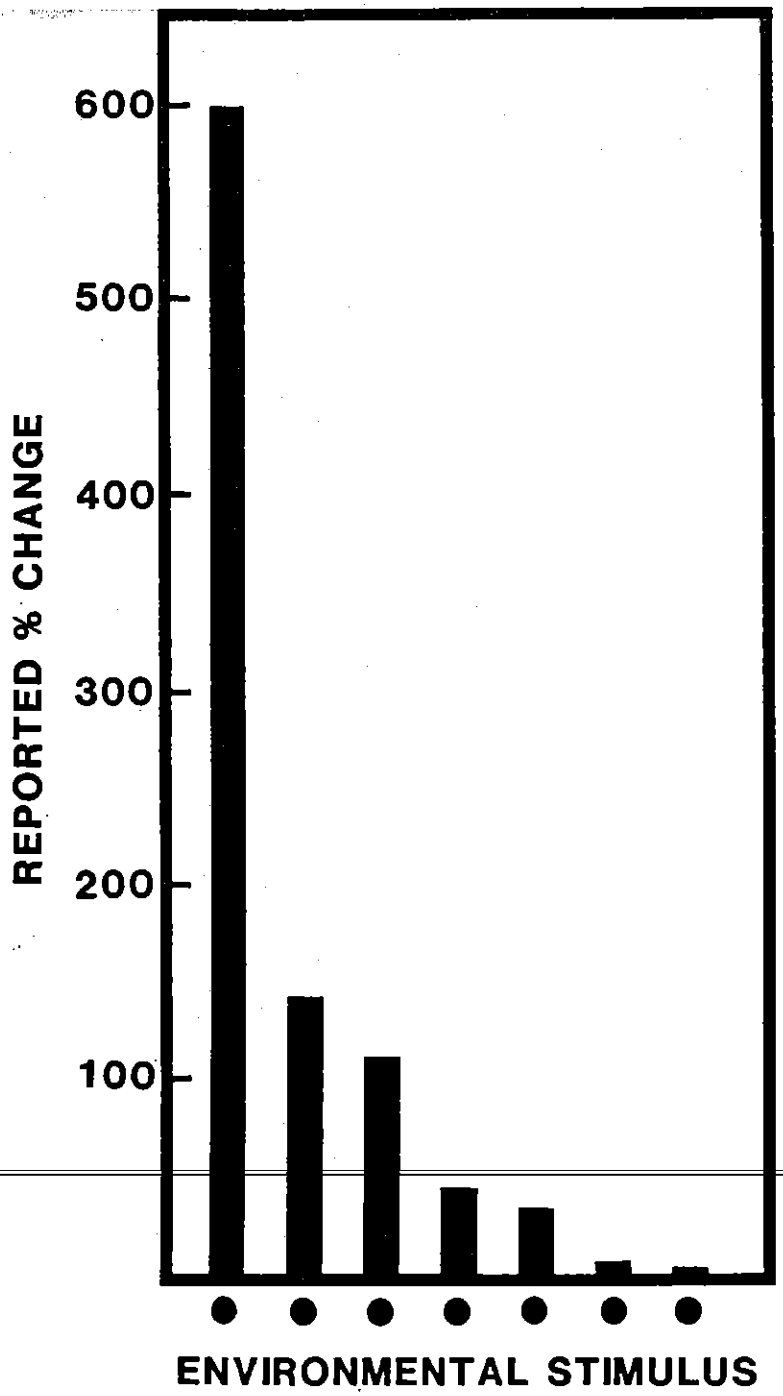
Author & Year	Environmental Stimulus	Reported Change
Sargent & Davies, 1973	Exercise	600.0%
Skinner et al., 1973	Exercise	142.9
Borg, 1982	Exercise	112.5
Faria & Drummond, 1982	None (daily variation over time, 2 PM to 2 AM)	45.0
Pandolf et al., 1984	Exercise	32.0
Inbar et al., 1982	10^5 (-) ions/cm^3	5.6
Sovijarvi et al., 1979	10^4 (+/-) ions/cm^3	3.6

6-3-5

ENVIRONMENTAL STIMULI: HUMAN PERCEIVED EXERTION

- None (daily variation over time, 2 PM to 2 AM)
- Exercise
- $\pm 10^4$ ions/cm^3
- -10^5 ions/cm^3

COMPARISON:
HUMAN PERCEIVED EXERTION



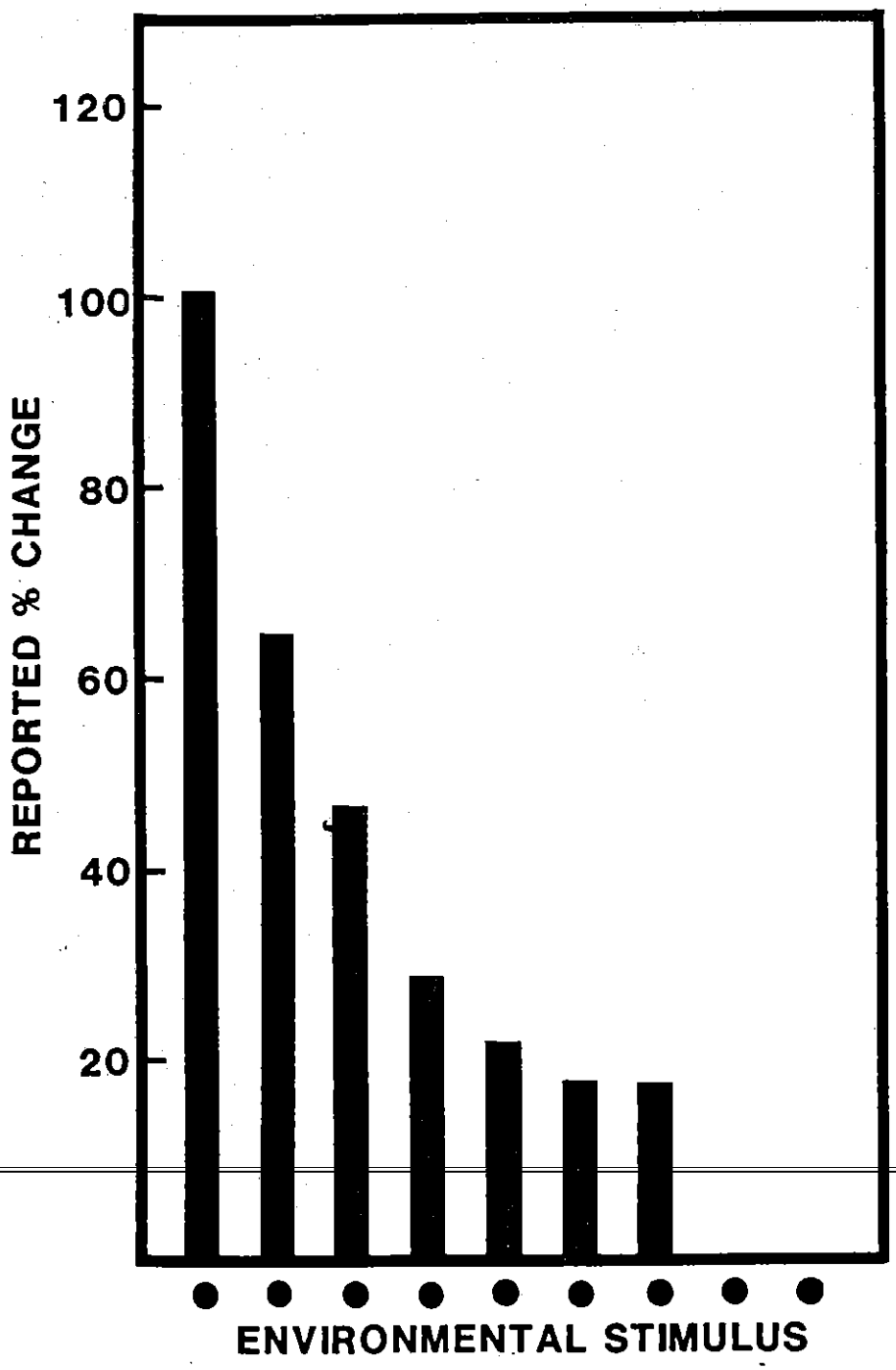
COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
ANIMAL RESPIRATION RATE

Author & Year	Environmental Stimulus	Reported Change
Stupfel & Pletan, 1983	None (daily variation over time, 4:30 AM to 7:30 PM)	106.3%
Stupfel & Pletan, 1983	Change from dark (night) to light (morning)	65.0
Brooks & White, 1978	Exercise	47.3
Lamm et al., 1982	None (difference in being drowsy vs. awake)	28.9
Gleeson et al., 1983	Exercise training	22.2
Bachman et al., 1965	10^5 (+) ions/cm^3	17.7
Bachman et al., 1965	10^5 (-) ions/cm^3	17.6
McDonald et al., 1965	10^5 (+) ions/cm^3	0
McDonald et al., 1965	10^5 (-) ions/cm^3	0

ENVIRONMENTAL STIMULI: ANIMAL RESPIRATION RATE

- None (daily variation over time, 4:30 AM to 7:30 PM)
- Change from dark (night) to light (morning)
- Exercise
- None (difference in being drowsy vs. awake)
- Exercise training
- $\pm 10^5$ ions/cm^3

COMPARISON:
ANIMAL RESPIRATION RATE



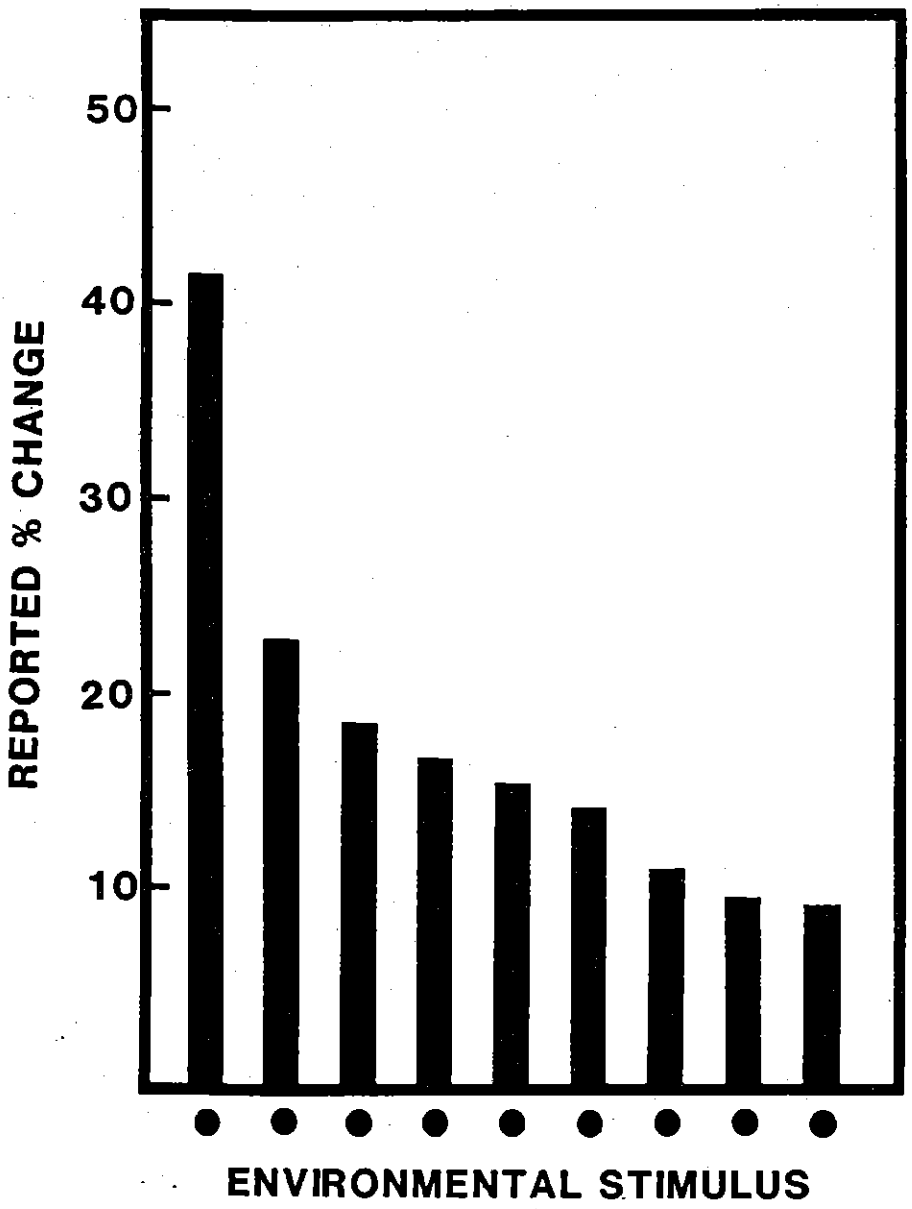
COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
ANIMAL HEART RATE RESPONSES

Author & Year	Environmental Stimulus	Reported Change
Haroutunian & Campbell 1981	Light bulb (60 watts) over time (30 minutes)	41.7%
Haroutunian & Campbell 1981	None (differences in age)	22.9
Haroutunian & Campbell 1981	"White" noise over time (30 minutes)	16.8
Berry et al., 1984	14°F change in temperature (68° - 82°)	18.6
McDonald et al., 1965	10^5 (+) ions/cm^3	15.5
Benessiano et al., 1983	None (differences in type of rat)	14.1
McDonald et al., 1965	10^5 (-) ions/cm^3	11.0
Bachman et al., 1965	10^5 (+) ions/cm^3	9.6
Bachman et al., 1965	10^5 (-) ions/cm^3	9.1

ENVIRONMENTAL STIMULI: ANIMAL HEART RATE RESPONSES

- Light bulb (60 watts) over time (30 minutes)
- None (differences in age)
- "White" noise over time (30 minutes)
- 14° F change in temperature (68° - 82°)
- None (differences in type of rat)
- $\pm 10^5$ ions/cm^3

COMPARISON:
ANIMAL HEART RATE RESPONSES



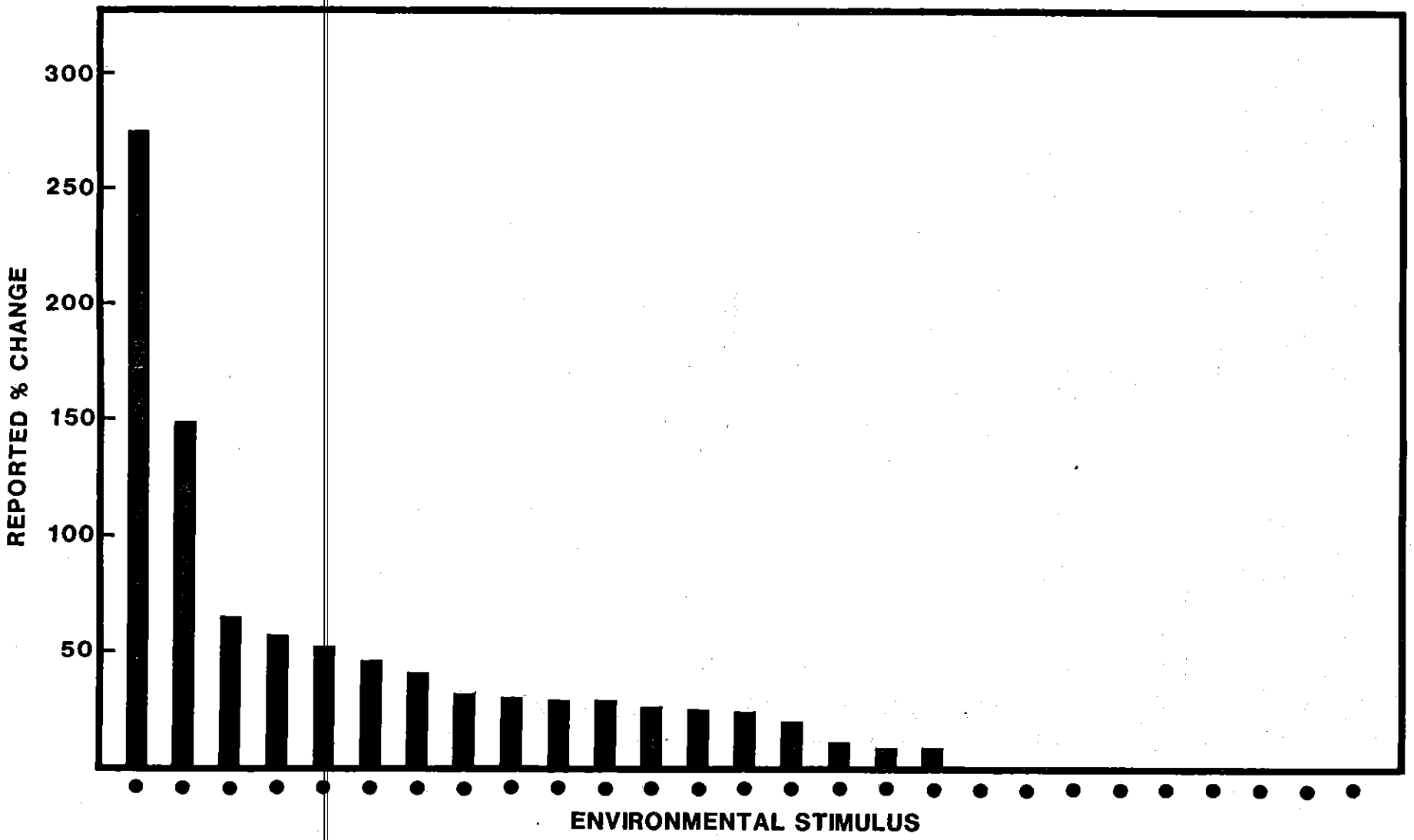
COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
ANIMAL NEUROCHEMICAL RESPONSES

Author & Year	Environmental Stimulus	Reported Change
Yates & Herbert, 1976	None (daily variation over time, 12 AM to 6 AM)	275.0%
Kempf et al., 1982	None (daily variation, night vs. day)	149.2
Diamond et al., 1980	10^5 (-) ions/cm^3	65.7
Diamond et al., 1980	Social environment	57.1
Morgan et al., 1975	None (daily variation over time, 12 AM to 4 AM)	52.2
Albrecht et al., 1956	None (daily variation over time, 11 AM to 7 PM)	45.8
Scheving et al., 1968	None (daily variation over time, 12 PM to 6 PM)	41.2
Udermann & Fischer, 1982	10^4 (+) ions/cm^3	31.8
Everett, 1976	None (different types of rats)	31.1
Fernstrom & Wurtman, 1972	2 hours after eating	29.4
Krueger et al., 1966	10^5 (+) ions/cm^3	28.9
Ray & Barrett, 1975	None (differences in male vs. female)	26.2
Wurtmann & Fernstrom, 1972	Diet and daily variation over time, (6 AM to 6PM)	25.4
Krueger et al., 1963	10^4 (+) ions/cm^3	24.4
Gilbert, 1973	10^3 (-) ions/cm^3	20.1
Krueger et al., 1968	10^5 (-) ions/cm^3	10.6
Krueger & Kotaka, 1969	10^5 (+) ions/cm^3	8.5
Krueger & Kotaka, 1969	10^5 (-) ions/cm^3	8.5
Undermann & Fischer, 1982	10^4 (-) ions/cm^3	0
Krueger & Kotaka, 1969	10^4 (+) ions/cm^3	0
Krueger & Kotaka, 1969	10^4 (-) ions/cm^3	0
Krueger et al., 1968	10^5 (+) ions/cm^3	0
Diamond et al., 1980	10^5 (-) ions/cm^3	0
Bailey & Charry, 1983	10^5 (+) ions/cm^3 10^5 (-) ions/cm^3	0 0
Charry & Bailey, 1985	10^5 (+) ions/cm^3 10^5 (-) ions/cm^3	0 0

ENVIRONMENTAL STIMULI: ANIMAL NEUROCHEMICAL RESPONSES

- None (daily variation over time, 12 AM to 6 AM)
- None (daily variation, night vs. day)
- Social environment
- None (daily variation over time, 12 AM to 4 AM)
- None (daily variation over time, 11 AM to 7 PM)
- None (daily variation over time, 12 PM to 6 PM)
- None (different types of rats)
- 2 hours after eating
- None (differences in male vs. female)
- Diet and daily variation over time, 6 AM to 6 PM)
- -10^3 ions/cm^3
- $\pm 10^4$ to $\pm 10^5$ ions/cm^3

COMPARISON:
ANIMAL NEUROCHEMICAL RESPONSES



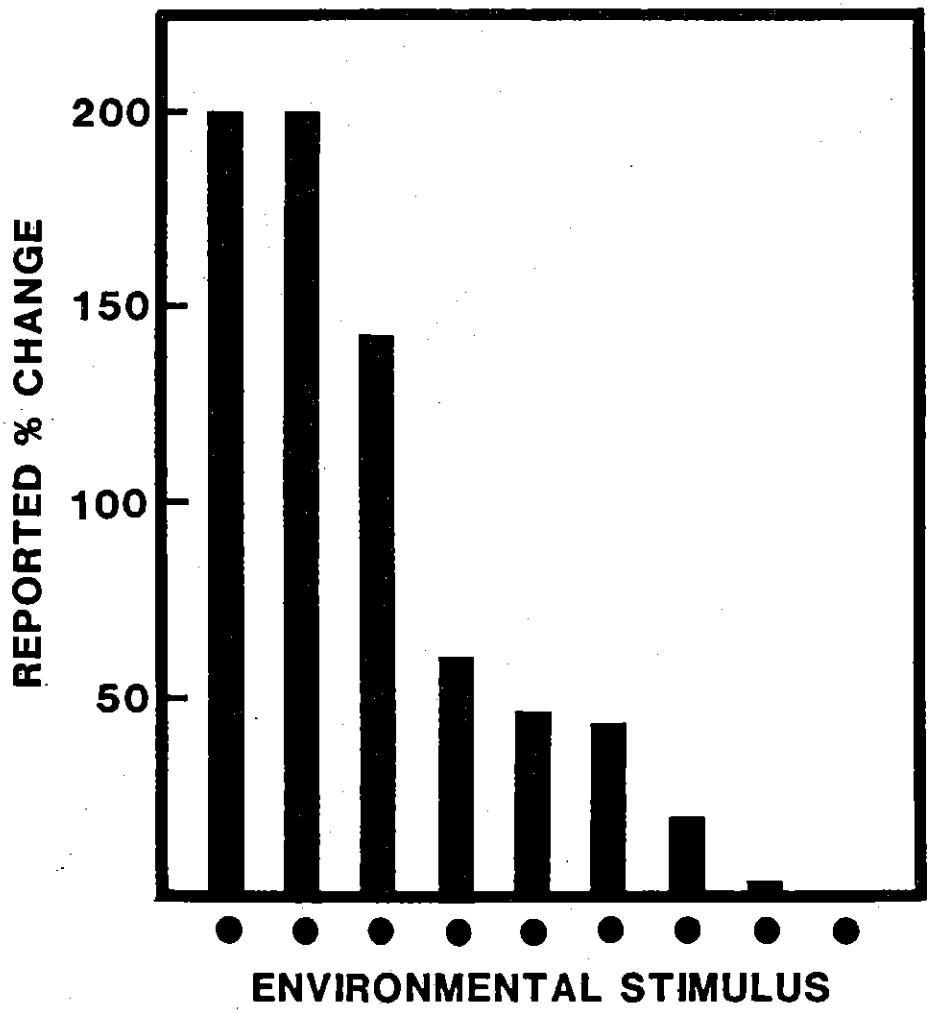
COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
ANIMAL BRAIN WAVE RESPONSES

Author & Year	Environmental Stimulus	Reported Change
Leung et al., 1982	Differences within the brain during walking activity	200.0%
Rosadini et al., 1981	Effects of learning	200.0
Cattarelli et al., 1979	Sleep vs. waking during stimulation	143.5
Olivereau et al., 1981	10^4 (+) ions/cm^3	59.9
Kleinlogel & Hausammann, 1980	None (time passing, 1 hour)	46.7
Cattaelli et al., 1979	None (sleep vs. waking)	42.1
Lambert et al., 1981	10^4 (+) ions/cm^3	18.4
Olivereau et al., 1981	10^4 (-) ions/cm^3	5.6
Lambert et al., 1981	10^4 (+) ions/cm^3	0

ENVIRONMENTAL STIMULI:
ANIMAL BRAIN WAVE RESPONSES

- Differences within the brain during walking activity
- Effects of learning
- Sleep vs. waking during stimulation
- None (time passing, 1 hour)
- None (sleep vs. waking)
- $\pm 10^4$ ion/cm^3

COMPARISON:
ANIMAL BRAIN WAVE RESPONSES



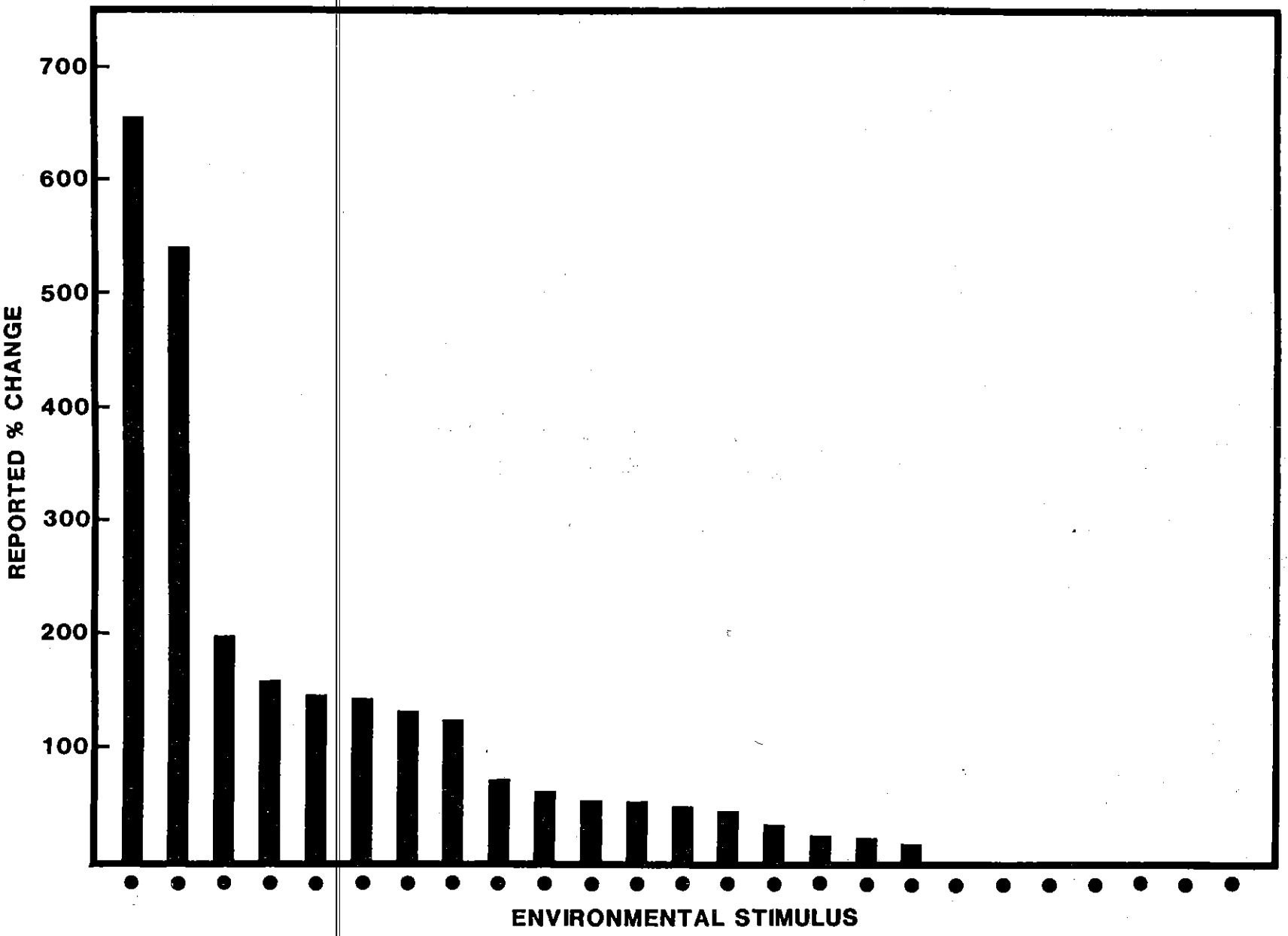
COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
ANIMAL ACTIVITY

Author & Year	Environmental Stimulus	Reported Change
Ray & Barrett, 1975	None (differences in type of rat)	657.1%
Ray & Barrett, 1975	None (time passing, 4 days)	542.9
Bachman et al., 1966	10^6 (+) ions/cm^3	200.0
Blizzard et al., 1975	Experience and differences in male vs. female	160.0
Lambert & Olivereau, 1980	10^4 (-) ions/cm^3	147.0
Olivereau & Lambert, 1981	10^4 (-) ions/cm^3	144.4
Ray & Barrett, 1975	None (differences in male vs. female)	133.0
Bachman et al., 1966	10^6 (-) ions/cm3	125.0
Lambert & Olivereau, 1980	10^4 (+) ions/cm^3	71.4
Olivereau, 1979	10^5 (-) ions/cm^3	61.0
Olivereau, 1970a	10^5 (+/-) ions/cm^3	32.0
Olivereau, 1979	10^5 (+) ions/cm^3	21.0
Olivereau, 1970b	10^5 (-) ions/cm^3	15.0
Olivereau & Lambert, 1981	10^4 (+) ions/cm^3	0
Bailey & Charry, 1984	10^5 (+) ions/cm^3 10^5 (-) ions/cm^3	0 0
Nazzaro et al., 1967	10^5 (-) ions/cm^3	53.9
Jordan & Solkoloff, 1959	10^3 (-) ions/cm^3	53.7
Falkenberg & Kirk, 1977	10^5 (+/-) ions/cm^3	49.7
Nazzaro et al., 1967	10^5 (+) ions/cm^3	45.9
Terry et al., 1969	10^7 (-) ions/cm^3	23.0
Lambert & Olivereau, 1980	10^4 (-) ions/cm^3	0
Olivereau & Lambert, 1981	10^4 (-) ions/cm^3	0
Olivereau & Lambert, 1981	10^5 (+) ions/cm^3	0
Duffee & Koontz, 1965	10^5 (+) ions/cm^3	0

ENVIRONMENTAL STIMULI:
ANIMAL ACTIVITY

- None (differences in type of rat)
- None (time passing, 4 days)
- Experience and differences in male vs. female)
- None (differences in male vs. female)
- $\pm 10^4$ to $\pm 10^6$ ions/cm^3

COMPARISON:
ANIMAL ACTIVITY



COMPARISON CHART
AIR IONS AND TYPICAL BIOLOGICAL VARIABILITY
ANIMAL LEARNING OF TASKS

Author & Year	Environmental Stimulus	Reported Change
Gardner et al., 1975	Perceptually stimulating environment	5633.5%
Satinder & Hill, 1974	None (different types of rats)	952.6
Gardner et al., 1975	Social environment	846.0
Ray & Barrett, 1975	Learning experience over 10 days	700.0
Berger & Brush, 1975	Type of learning experience	511.0
Ray & Barrett, 1975	None (different types of rats)	350.0
Duffee & Koontz, 1965	10^5 (-) ions/cm^3	218.2
Lambert & Olivereau, 1980	10^4 (+) ions/cm^3	104.2
Olivereau & Lambert, 1981	10^4 (+) ions/cm^3	100.0
Ray & Barrett, 1975	None (differences in male vs. female)	90.9
Lambert & Olivereau, 1980	10^4 (+) ions/cm^3	86.5
Olivereau & Lambert, 1981	10^5 (-) ions/cm^3	75.4
Olivereau & Lambert, 1981	10^4 (+) ions/cm^3	58.8

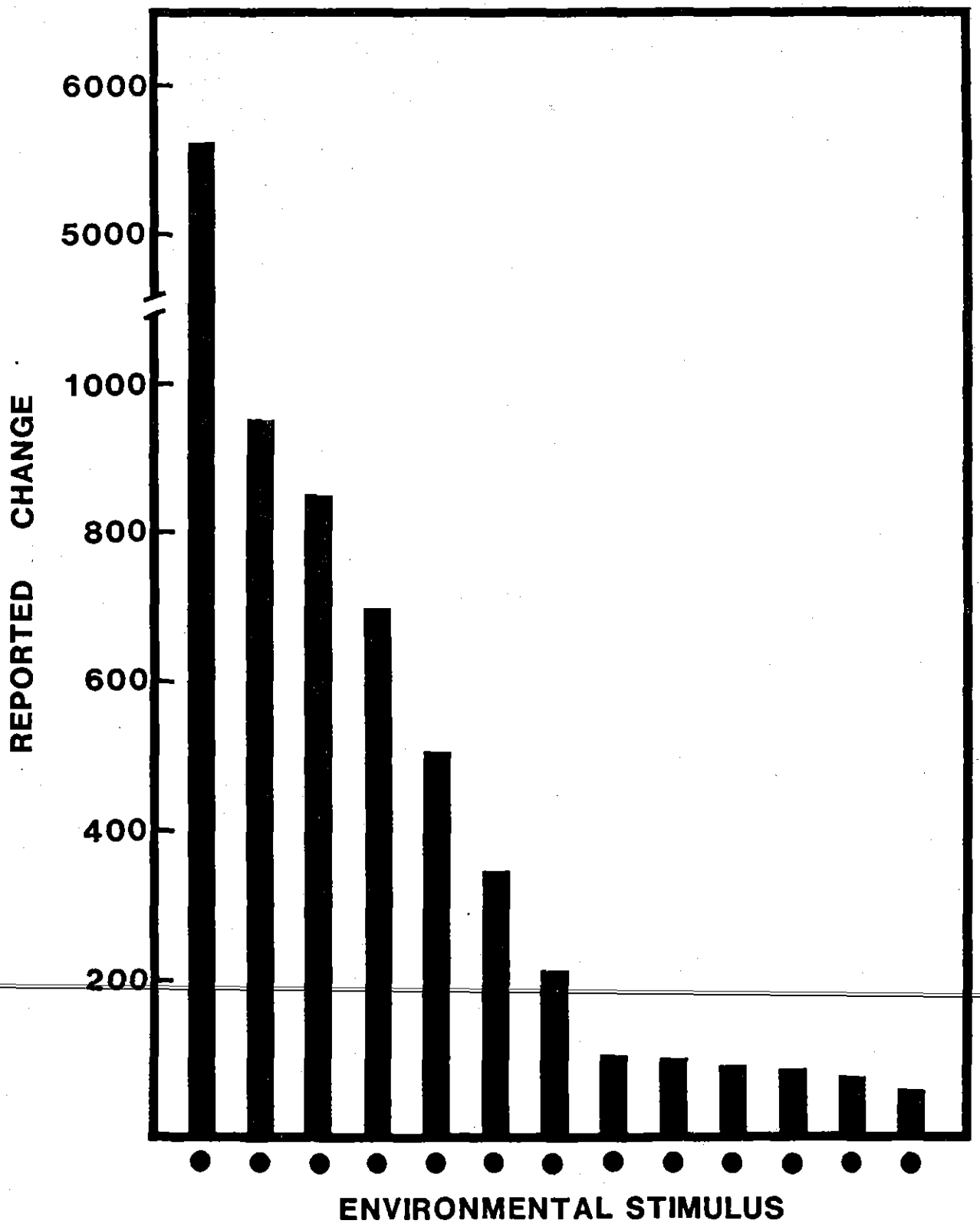
ENVIRONMENTAL STIMULI: ANIMAL LEARNING OF TASKS

6-3-3

- Perceptually stimulating environment
- None (different types of rats)
- Social environment
- Learning experience over 10 days
- Type of learning experience
- None (different types of rats)
- None (differences in male vs. female)
- $\pm 10^3$ to $\pm 10^5$ ions/cm^3
- (-) 10^7 ions/cm^3

COMPARISON:

ANIMAL LEARNING OF TASKS



LONG-TERM EXPOSURE ANALYSIS

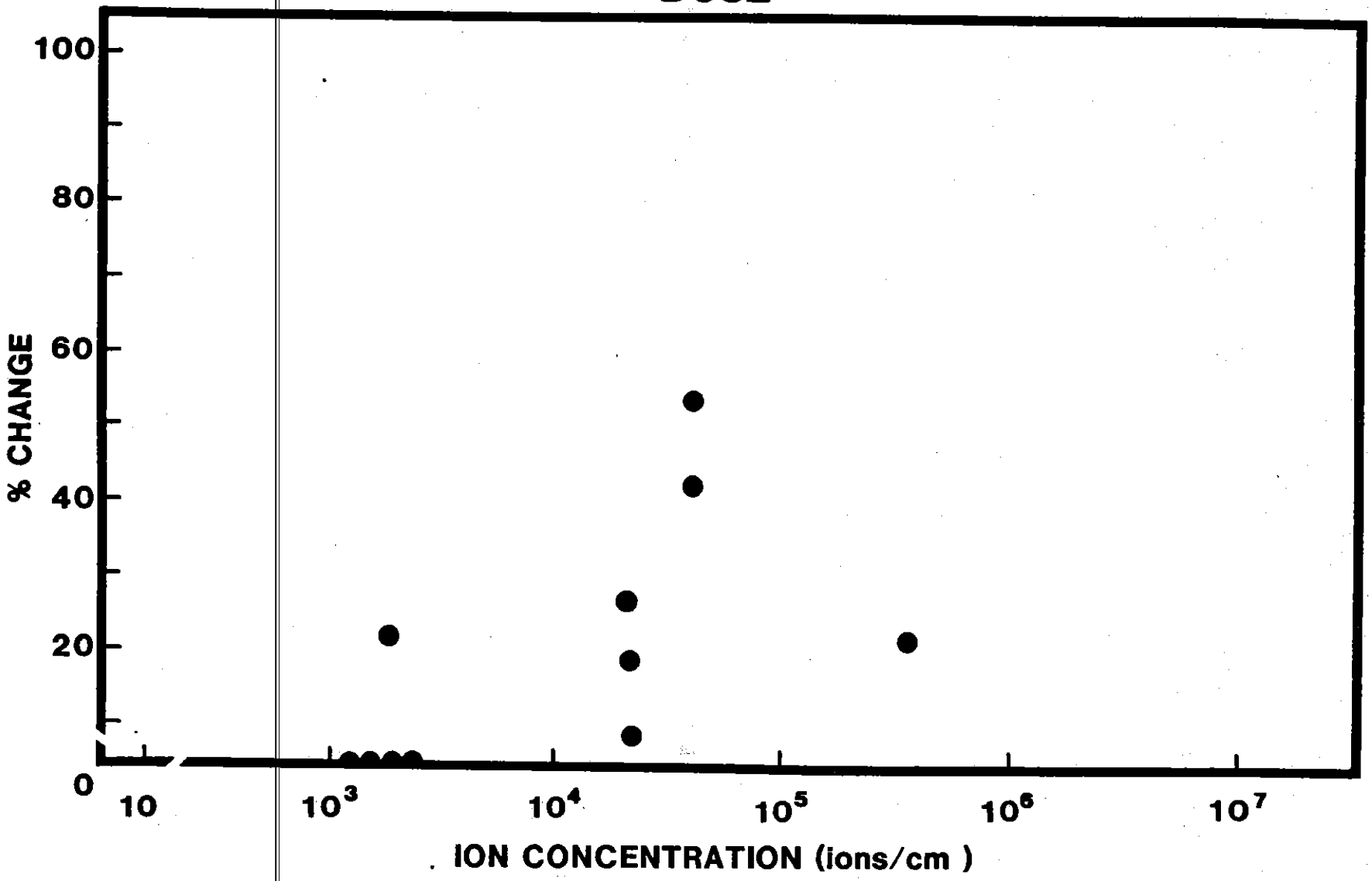
- 13 studies examined
- Equivalent ion exposure levels determined
- Equivalent ion exposure periods determined
- Magnitude of effect calculated
- Dose-response assessed
- Time-course assessed

Results

LONG-TERM EXPOSURE ANALYSIS

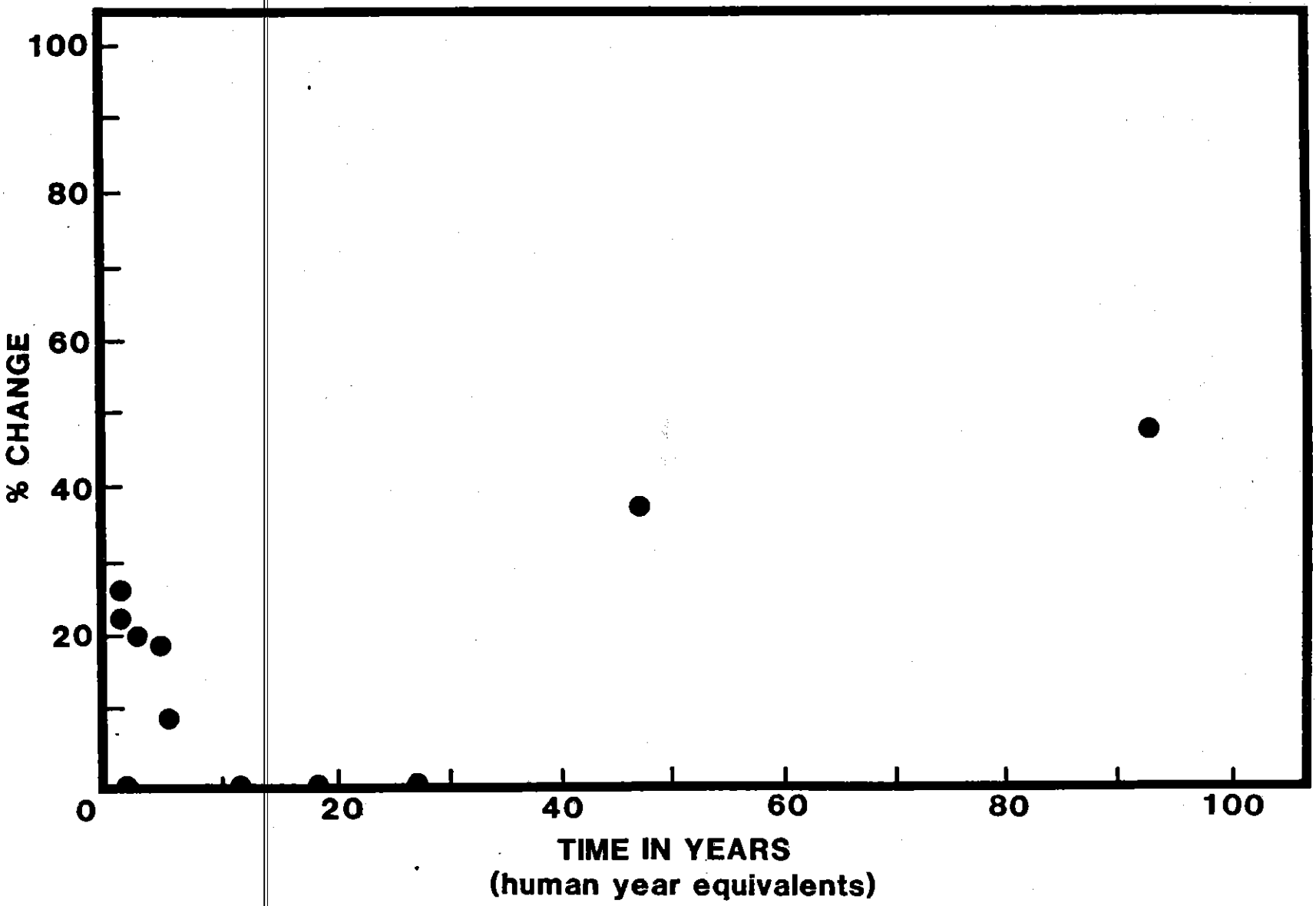
- Equivalent exposure levels range from 10^3 to 10^5 ions/cm^3
- Equivalent exposure periods range from 1.5 to 94 years
- Magnitude of effect - within normal biological variability
- No dose-response relationship
- No time-course relationship

LONG TERM BIOLOGICAL RESPONSES TO IONS: DOSE



LONG TERM BIOLOGICAL RESPONSES TO IONS:

TIME - COURSE



HIGH VOLTAGE TRANSMISSION LINES AND HEALTH: THE PROBLEM

- Risk Perception
- Misinformation
- Uncertainty concerning physical health risks

DIAGNOSIS AND MANAGEMENT OF RISK PERCEPTION

BASIC ELEMENTS

- Exposure to information
- Processing and interpretation of information
- Formation of belief structure

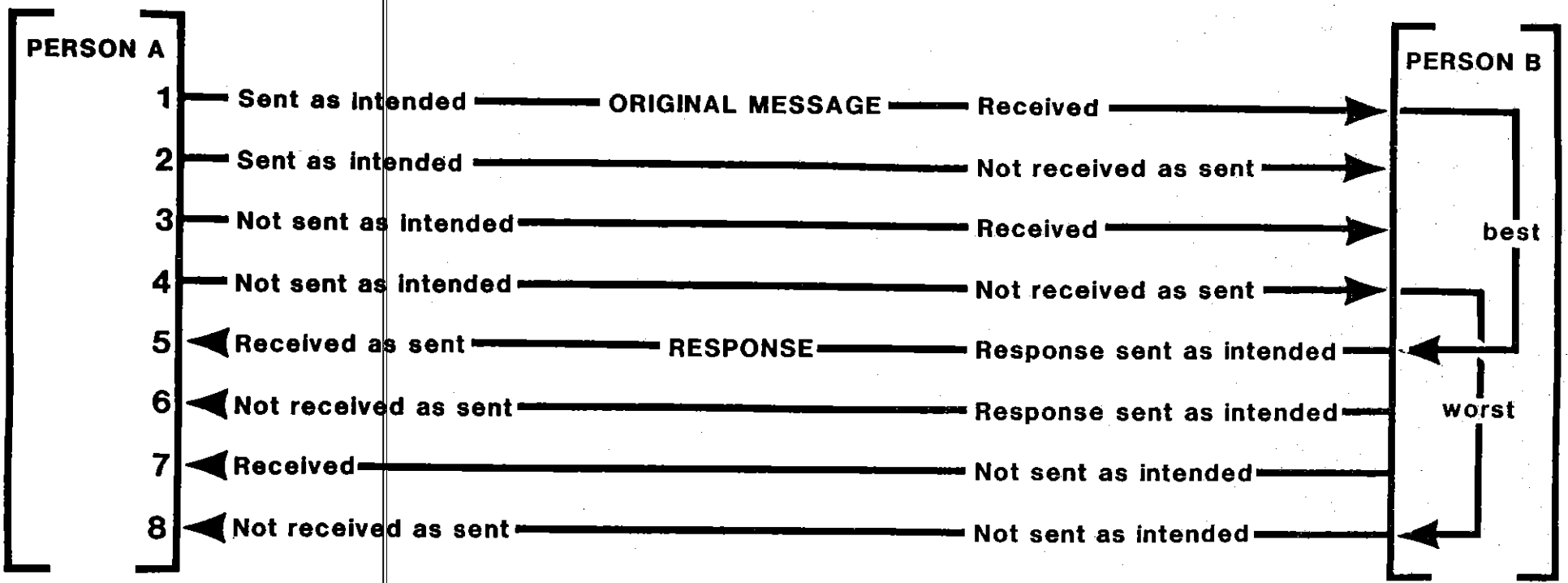
PSYCHOLOGICAL FACTORS

- Prior knowledge
- Proximity
- Recency
- Source credibility
- Ability to exert control

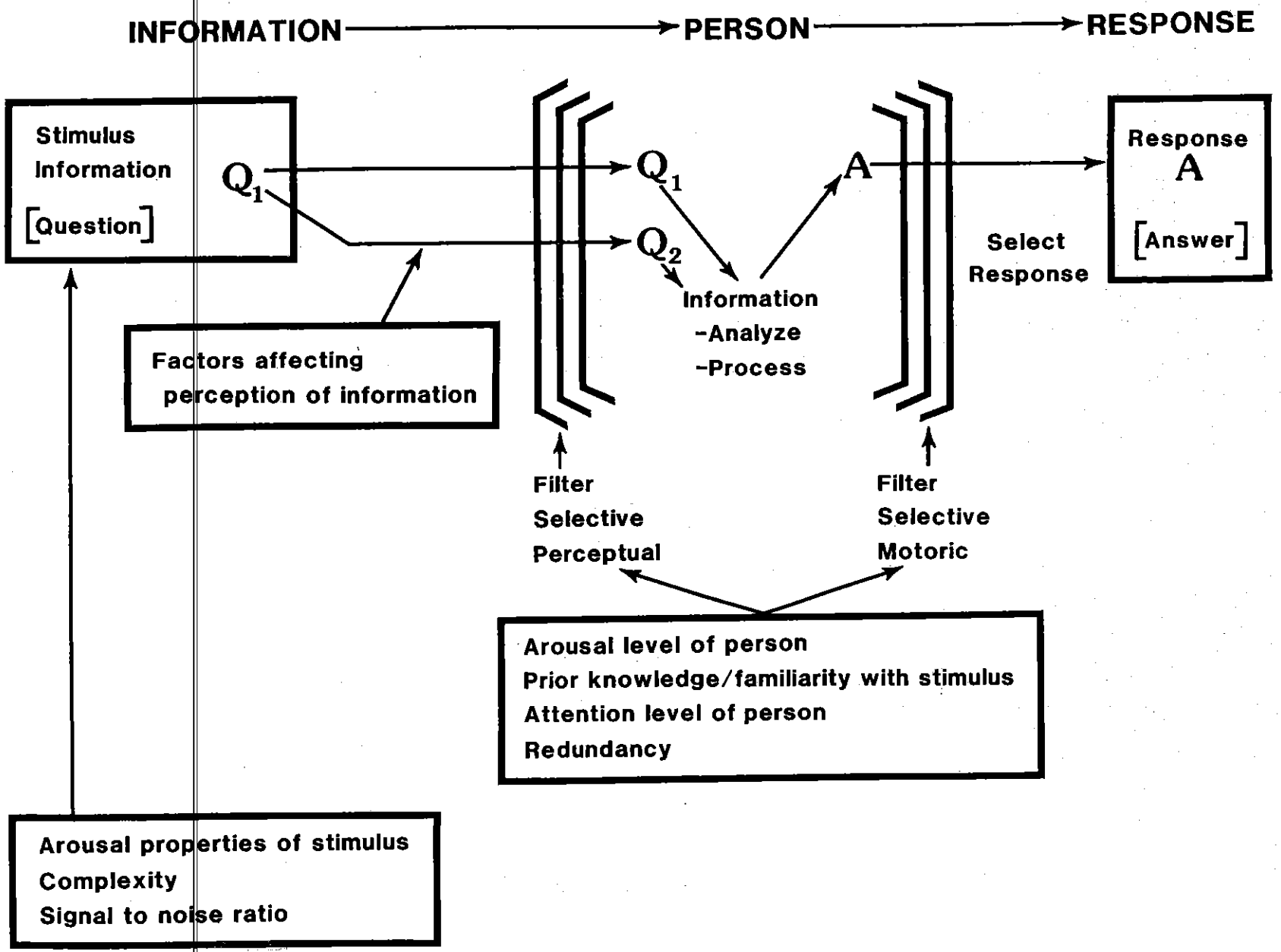
CONSEQUENCES OF RISK PERCEPTION

- Mass psychogenic illness
- Psychosomatic illness
- Stress induced illness

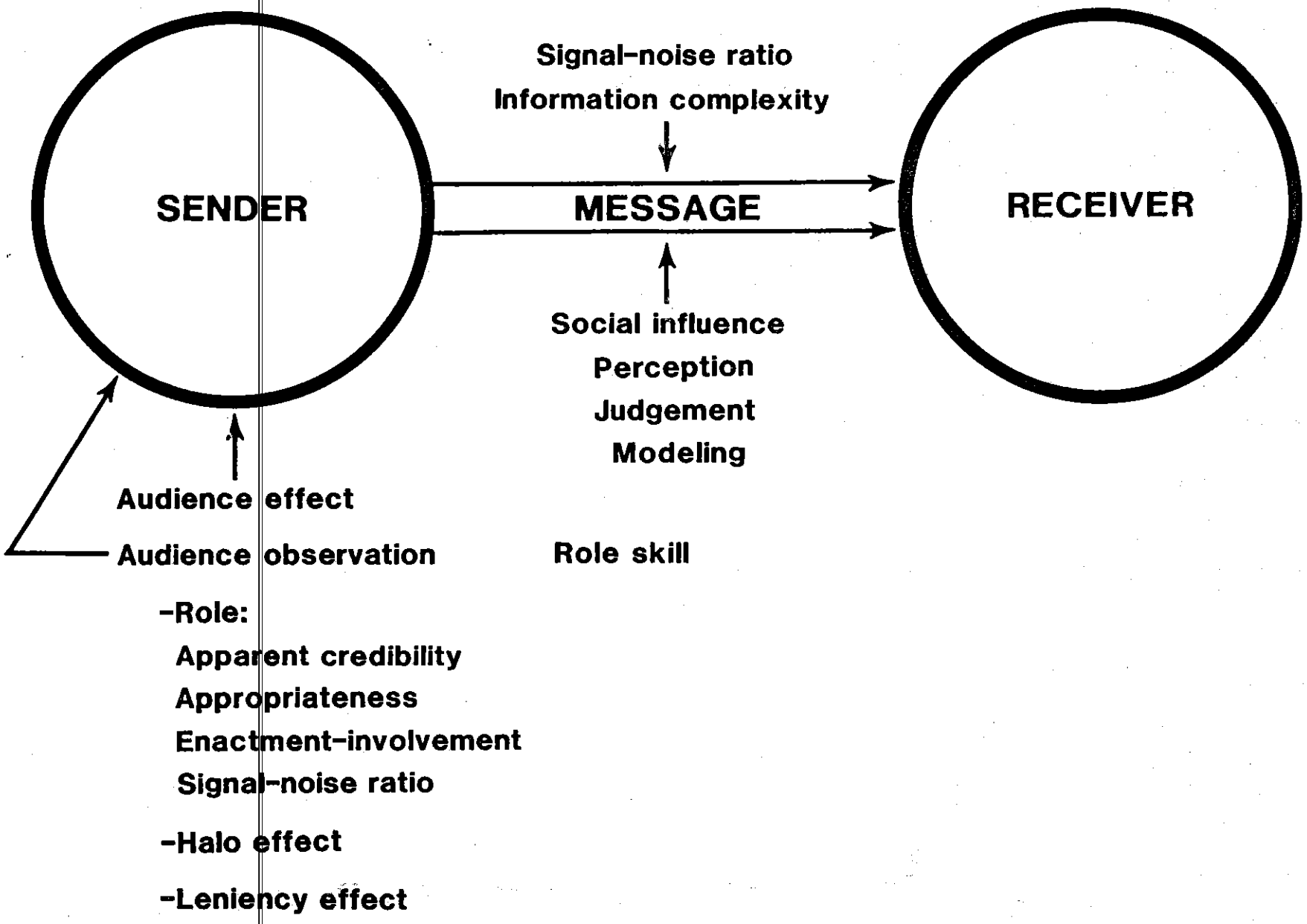
FACTORS AFFECTING INFORMATION FLOW: DYADIC INTERACTION



QUESTION AND ANSWER SEQUENCE



CREDIBILITY-IMPACT SEQUENCE



Perception of Risk: Health Effects Issues Frequently Appearing in Media

- Combined effects
- Electromagnetic fields cause cancer and birth defects
- Minnesota residents have legitimate complaints about the dc lines
- Long-term effects, no studies, further research needed
- Texas PUC did a public service for the Texas citizens by preventing the permit

ERI SOLUTIONS: CASE ILLUSTRATION

- New England Electric/Hydro-Quebec ± 450kV DC line
- Hydro power from Canada to US to supply 10% of New England's energy needs starting in 1991
- Project cost $1.5-2.0 billion
- Project revenue several billion dollars to Hydro-Quebec and hundreds of millions in savings to New England
- Health effects electromagnetic fields critical issue
- Strategic approach